DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

WATER-SUPPLY PAPER 398

GROUND WATER

IN

SAN JOAQUIN VALLEY, CALIFORNIA

BY

W. C. MENDENHALL, R. B. DOLE
AND HERMAN STABLER

WASHINGTON
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By W. C. Mendenhall, R. B. Dole, and Herman Stabler.

INTRODUCTION.

By W. C. Mendenhall.

DEVELOPMENT OF IRRIGATION IN THE SOUTHWEST.

The agricultural industry in the southwestern part of the United States is peculiar in that within that region consumption tends constantly to exceed production. This condition is due to the large areas of desert, which are unsuited for agriculture but support many other industries. The irrigated land in the 11 arid States, lying for the most part west of the crest of the Rocky Mountains, was 7,254,110 acres in 1899, when the Twelfth Census was taken, and 13,202,889 acres in 1909, when the Thirteenth Census was taken. Although irrigation development has not been so rapid since 1909 as during the preceding decade, it has nevertheless continued, and large tracts are added each year to the reclaimed areas through the operation of the reclamation act, the Carey Acts, the desert-land law, and the development of lands in private ownership. Meanwhile general industrial expansion continues, although less rapidly than at earlier periods, and under the influence of this expansion and the pressure of population from the East most of the Western States are making important additions to their population each year.

In the States of Nevada, Arizona, and New Mexico the mining industry becomes yearly of greater importance, and the influx of people engaged in it is increasing correspondingly. The increase in the production of petroleum in California from 395,000 barrels in 1892 to 14,000,000 barrels in 1902 and 86,450,000 barrels in 1912 represents an amazing growth in an industry and in the population necessary to support it, which in turn greatly increases the demand for food products and thus stimulates agricultural development. The growth of trade with oriental countries and the development of the mineral resources of Alaska have resulted in great accessions to the population of the Pacific coast seaports, particularly those about San Francisco Bay and Puget Sound, and in greatly increased

demands for food products. The passage in 1914 of an Alaskan railroad bill promises to increase the northern market during the construction period at least, and the completion of the Panama Canal will open eastern and European markets to certain types of Pacific coast products, to which these markets are now closed. Southern California, as that portion of the State lying south of the Tehachapi Mountains is called, has become established as a playground for the people of the entire United States, and of the thousands of tourists who visit this area each year many become permanent residents.

Of the areas in the Southwest within which food products for its cities, its tourist centers, and its mining regions must be raised, the largest and most promising is the interior lowland known as the Great Central Valley of California. The southern segment of this lowland, San Joaquin Valley, contains about 7,500,000 acres, of which 1,728,975 acres was under irrigation in 1912(?). Southern California contains approximately a million acres of land that would be cultivable if water were applied to it; yet in this region, where the water resources are fully utilized, perhaps a quarter of a million acres are under irrigation, and the remaining area either is nonproductive or yields a relatively low-grade and uncertain crop through the application of dry-farming methods.

Furthermore, the density of population in the irrigated valleys south of the Tehachapi and the large and rapidly growing cities there means the consumption of practically all the staple food products raised. Fruits, especially the citrus varieties, are grown for export, and in some years more grain is produced than is necessary for local needs; but in general the demand in this area for food staples is in excess of the local supply and this condition will be accentuated rather than ameliorated in the future.

Imperial Valley, in extreme southeastern California, is rapidly becoming a very productive area through the utilization of Colorado River water, and many other sections might be mentioned whose acreage will increase the total area under irrigation, but all of them together are smaller than San Joaquin Valley, which, with that of the Sacramento, must become the chief agricultural district of the Southwest.

The agricultural development of this valley is controlled by the distribution of rainfall, the character of the soils, and the possibility of applying other water than that which reaches the valley as a direct result of precipitation upon its surface. Its extreme southern end, in the vicinity of Bakersfield, is strictly arid, the average rainfall there being less than 5 inches. Precipitation increases gradually toward the north, until at Red Bluff, in the northern end of Sacramento Valley, the annual rainfall averages 25.7 inches. Intermediate areas receive an amount of precipitation intermediate between these

two extremes; but south of San Francisco Bay the available records indicate a rainfall of less than 16 inches, and over the greater part of this area, of less than 12 inches—an amount insufficient to insure crops, even of grain, and entirely inadequate for the other diverse food crops which a dense population demands.

The progressive increase in aridity from the northern toward the southern end of the valley trough prevails to an equally marked extent east of the valley, in the mountain areas from which its surface waters are drawn. The total run-off from the Sierra, according to the best available records, is about 12,000,000 acre-feet annually. Of this amount, 3,300,000 acre-feet is supplied by the streams from Kings River southward and 8,700,000 acre-feet by the streams north of Kings River. The combined drainage area of the streams from Kings River southward is 4,871 square miles; that of the streams north of Kings River is 7,714 square miles. That is, a southern portion of the Sierra, whose area is nearly seven-tenths as large as the northern portion, yields but one-third as much water in the form of stream discharge. Hence in the south end of San Joaquin Valley the acreage which is irrigable by the use of surface waters is very much less than that in the northern end of the valley, and the area available for development there is correspondingly greater than that available farther north.

The question of water supply is, of course, not the only one that confronts those who desire to see the development of San Joaquin Valley proceed rapidly, although it is properly regarded as the most pressing. The quality of the soil, particularly with reference to the presence of hardpan or of alkali, is of the utmost importance. Extensive alkali areas exist along the axis of the valley and part way up its eastern slope, especially at points where the ground waters lie close to the surface, and hardpans of at least two types underlie some of the higher and otherwise most valuable lands. These soil problems are being studied systematically by the soil experts of the Department of Agriculture [1] and the reports that are issued should be supplemented as rapidly as possible, until definite information as to soils is available for the entire valley.

The conditions already outlined—namely, the great actual and the much greater prospective importance of San Joaquin Valley as an agriculturally productive center—have led during the last decade to greatly increased interest in the possibility of adding to the acreage under irrigation, and hence to the output in food products.

Irrigation enterprises, like those based upon other industries, invariably pass through a pioneer stage, in which only the most easily

[1] Lapham, Macy H., and Heileman, W. H., Soil survey of the Hanford area, California: U. S. Dept. Agr., Bur. Soils, Field Operations 1901. The results of similar surveys are available for areas about Bakersfield, Modesto, Turlock, Madera, Fresno, Portersville, and Stockton.

accessible resources are utilized. In this stage the land holdings are large, the methods of application of water are wasteful, and the agricultural output is low. Only later, when the population becomes much more dense and the need of greater output is clearly recognized, do methods so improve that the ratio of output to area, to resources, and to investment becomes such as to satisfy reasonable economic demands.

In southern California irrigation methods have been carried to a greater degree of refinement than in any other section of the United States. When irrigation began there, during the first third of the nineteenth century, short crude ditches were constructed by which the waters utilized were diverted from the lower courses of the streams to near-by lands upon which they were turned, and the only products were grain and pasture, by which the flocks and herds were carried through the dry season. Such methods were in vogue until the late sixties and early seventies, when American settlers entered the country and attempted to utilize lands that had been regarded as entirely worthless. These settlers brought with them capital, and constructed their ditches on higher lines and in a much better manner than were the old Spanish zanjas. They applied water much less lavishly, to larger areas, and with much better unit results, and so by continued improvements of this type all of the surface waters were finally utilized to the best advantage. But settlers continued to flock to the region, and attention was then turned to the underground waters, which were developed at first only to supplement the surface supplies. Such reservoir sites as were available were also filed upon and made use of, and eventually many enterprises were started, some of which depended on a combination of surface and underground waters, and others on underground waters alone. Still later refinements resulted in the reconstruction of many of the old ditches, the replacement of open canals by underground pipes, and the elimination thereby of waste by seepage and evaporation. In the lower lands wells were drilled which yielded flowing water, and stream waters which had previously been utilized on these lower lands were diverted to the bench lands, where products of higher value could be grown.

As a result of this intensity of development it is probable that in no area in the United States are the waters so thoroughly utilized as in the region that lies south of the Tehachapi Mountains. In their passage from the mountains, where they originate in precipitation, to the sea, where they are lost, some portions of these waters are used as many as eight times—in power plants, in irrigation from surface streams, and finally by the recovery of that portion of the surface flow which, sinking into the alluvial fans, augments the supply in the underground reservoirs.

Much of San Joaquin Valley is still in the pioneer stage of irrigation development, depending almost exclusively on surface waters, and in a large part of the area waste is great, over-use is the rule, and, as a consequence, minimum production results from a maximum use of water. But the pioneer stage is passing. Engineers trained in more refined methods are entering the region and applying their training. Special communities, like those about Portersville and Lindsay, where citrus fruits are raised, have for a decade or more used deep ground waters, whose cost greatly exceeds that of surface waters where the latter are available in other parts of the valley. This relatively high cost is amply justified, however, in the citrus belt by the great value of the product

In other parts of the valley, as, for example, in the neighborhood of Corcoran, capitalists who had profited in other regions through the use of flowing artesian waters have undertaken to develop colonies by utilizing waters of this type, whose existence had been proved years before by the owners of large cattle ranches, who had put down wells to obtain water for stock.

In still other districts, as about Bakersfield, Stockton, and Fresno, isolated individual pumping plants have been installed within the last decade, and by their use lands whose owners had been unable to secure rights to the limited supply of surface waters have been brought within the productive zone.

INVESTIGATIONS BY THE UNITED STATES GEOLOGICAL SURVEY.

These more or less isolated experiments and their successful outcome have resulted in a widespread recognition of the fact that the productivity of San Joaquin Valley can be greatly increased by the utilization of the heretofore neglected ground-water resources. This recognition has been followed logically by a desire for specific information as to the quality, occurrence, accessibility, character, and proper use of waters of this type.

In response to this demand the Geological Survey and the Reclamation Service began a study of the ground-water resources of the valley in 1905. This work was continued as funds became available in 1906 and 1907 by the engineers and geologists of the Survey, and in 1908 a preliminary report [1] was issued. The plan at that time in mind was to supplement the preliminary statistical study of developments by more comprehensive work on the geological conditions controlling the distribution and circulation of the ground waters, by a careful field reconnaissance of the chemical characteristics of the waters, since the preliminary work had revealed the importance of

[1] Mendenhall, W. C., Preliminary report on the ground waters of San Joaquin Valley, California: U. S. Geol. Survey Water-Supply Paper 222, 1908.

this element in the problem, and by a careful study of pumping costs under various conditions as developed by the experience of irrigators in the valley. The pressure of work in other directions has rendered it impossible to carry out this plan fully. Further field geologic studies have not been possible, but the chemical reconnaissance was completed by R. B. Dole in the fall of 1910, and his report, long ready for publication, is included as a part of this volume. Herman Stabler examined a large number of pumping plants in the valley during the same season, and the results of his studies are also included for the benefit of water users in the valley.

Certain detailed data omitted from Water-Supply Paper 222 but forming the basis of many of the conclusions reached in it are also now published. The tables of wells examined and their costs, equipment, and yields are referred to especially. As a number of years have elapsed since the completion of these tables, they do not summarize the later developments. The addition of later wells would add to the mass of data rather than alter the conclusions to be drawn, however, so that their omission is not considered to be of great significance.

In the preparation of Plates I and II the topographic and engineering map of San Joaquin Valley issued by the California State Engineering Department in 1886 has been used as a foundation. Some additions and corrections have been made as a result of later surveys, especially those made by the United States Geological Survey about Bakersfield and along the southern and western borders of the valley, but the earlier map has been used substantially in its original form for the greater part of the valley. On Plate I (in pocket) the area in which flowing wells may be obtained has been outlined with as much accuracy as the information at hand permits. Beyond the limits of the belt of flowing wells the attitude of the ground-water plane has been indicated by hydrographic contours which are based on the elevations of the surface as indicated by the topographic sketch contours of the base map. Neither set of contours is accurate in detail, but it is believed that the relations between the two—that is, the depths to ground water at various points—are correct within a reasonable margin of error, so that the map will be of practical value. It must be remembered, in using this map, that ground-water levels do not everywhere remain constant. On the deltas and in the irrigated areas there is a more or less regular annual variation in level, the plane of saturation rising during the high-water period—the period of maximum irrigation in early summer—and falling during the low-water period in the autumn and early winter. In the past there has been a marked permanent rise in the ground-water level in areas to which water has been applied by the construction of the large canals of the greater irrigation systems. This rise still con-

tinues in some localities, to which water has been applied for a number of years, and it will be marked in regions to which canal systems may be extended in the future, although the chief changes of this character have doubtless already been brought about. In one or two limited localities there is probably also a general decline in ground-water levels. It is not possible, of course, to indicate a varying water level by a single set of hydrographic contours. Those used indicate about the position and form of the water plane in the period from 1905 to 1907.

GEOGRAPHY OF THE VALLEY.

San Joaquin Valley and Sacramento Valley together constitute the Great Central Valley of California, with an area of nearly 16,000 square miles. (See fig. 1.) This level-floored depression is more than 500 miles long and varies from 20 to 50 miles in width. East of it the Sierra rises to an elevation between 14,000 and 15,000 feet above sea level, and west of it the lower Coast Ranges separate it from the Pacific. The greatest elevation of the Sierra is near its eastern edge and all its important drainage is westward toward the Great Valley, an important fact upon which the greater part of the actual and prospective agricultural value of the valley depends. The Coast Ranges are a series of parallel ridges of moderate elevation that inclose valleys, like those of the Salinas and Santa Clara, which, when not too arid, are highly productive.

The Great Valley itself exhibits little diversity in its physical aspect. Such differences as exist between its north and south ends are climatic, or, if physical, are directly due to climatic differences. Among local physical features based upon climatic differences may be mentioned the Tulare basin at the south end of San Joaquin Valley. The basin is due to the aridity of the region and the consequent extensive development of alluvial fans. Two of these, extending from Kings River on the east and Los Gatos Creek on the west side of the valley, have coalesced in a low ridge south of which lie the Tulare Lake and Kern Lake depressions. Basins different in character and situation, but originating nevertheless in climatic conditions, are the overflow basins of the Sacramento and the lower San Joaquin valleys, of which the Yolo basin may be mentioned as a type. These basins occupy the lowest portions of the flood plains just outside the ridges that form the immediate river banks.

The central valley opens to San Francisco Bay and thence to the Pacific through Carquinez Straits and the Golden Gate, and the combined drainages of the Sacramento and San Joaquin systems discharge through these gateways. Other passes, like the Tehachapi, the Tejon, and Walker Pass near the south end of San Joaquin Valley and the Livermore Valley gateway near Carquinez Straits, extend

across the mountain barriers that surround the central lowland, but they are not so low nor so pronounced as the central tidal gateway. In general it may be said that the Great Valley is completely inclosed except for this opening.

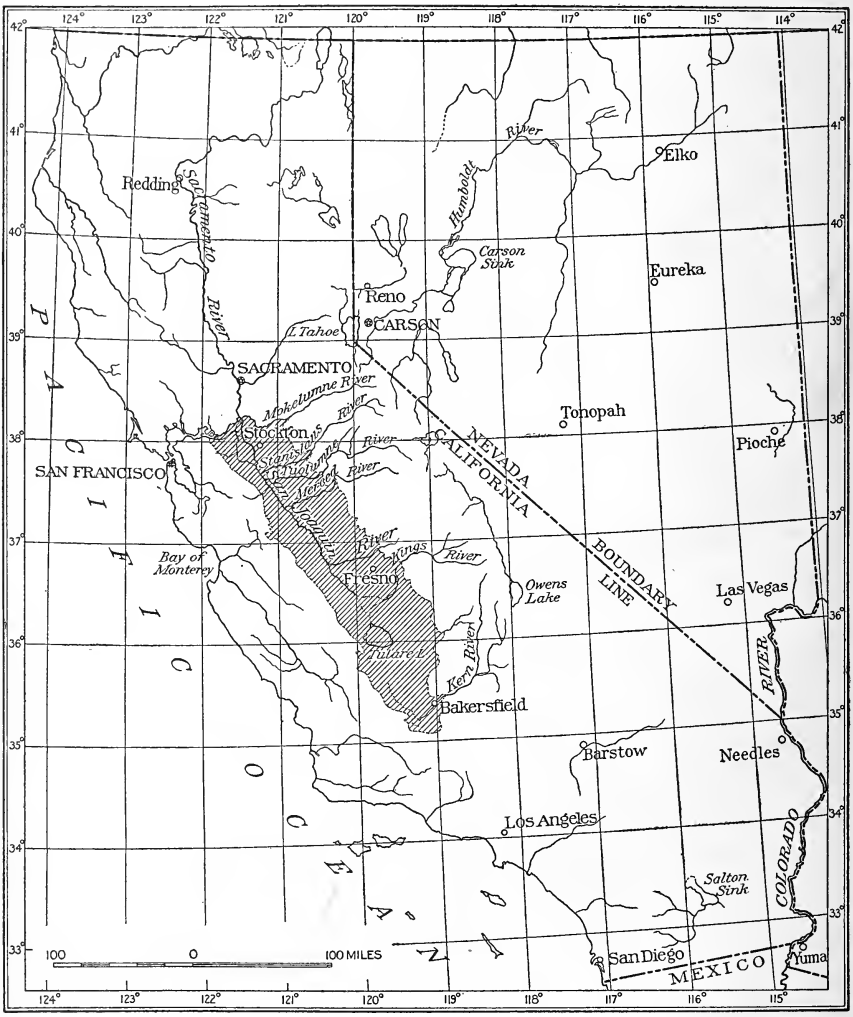

FIGURE 1.—Index map showing location of San Joaquin Valley (shaded area).

The larger lobe of the central depression, extending southward from Cosumnes River and Suisun Bay, is generally known as San Joaquin Valley, although it is not all drained directly by San Joaquin River and its tributaries. The southern, more arid third of the depression, extending from Kings River delta to Tehachapi Mountains, has no surface outlet under normal conditions, and the surplus surface waters accumulate in the Tulare Lake depression and Buena Vista

reservoir. Originally Kern Lake received a portion of the excess from Kern River, but through the protection afforded by a restraining dike water is kept out of it except when unusual floods break the restraining dam. The original lake bottoms have now become valuable wheat lands.

The streams that drain into the valley from the Sierra carry practically all of the water that reaches it. They are in every way more important than those that enter it from the west. They have larger drainage basins, individually and collectively; they have longer courses; and they flow from higher mountains, with a much greater rainfall and a better protective covering of forest and brush; hence their discharge is many times greater and much less erratic than that of the west-side streams.

The total drainage area[1] tributary to the valley from the Sierra is 16,089 square miles; from the Tehachapi and Coast ranges 4,293 square miles; and the area of the valley floor is 11,513 square miles. The total area of the San Joaquin basin is therefore 31,895 square miles.

The average run-off of the principal east-side streams north of Kings River, with a combined drainage area of 7,714 square miles, is about 8,700,000 acre-feet, while that of Kings, Kaweah, Tule, and Kern rivers, discharging into the Tulare basin from a watershed with an area of 4,871 square miles, is about 3,300,000 acre-feet. The total discharge into the valley from 12,585 square miles of Sierra watershed is therefore about 12,000,000 acre-feet.

The preponderance of east-side streams has given the valley floor its well-marked unsymmetrical form. The valley axis, the line of lowest depression, is throughout much nearer the western than the eastern foothills. In places it lies against these hills, but elsewhere, as between Los Gatos and Cantua creeks, the west-side slopes are 15 or 18 miles wide, at least one-half as wide as those of the east side. They are also steeper than those of the east. Grades of 20 or even 40 feet to the mile are not rare, and it is unusual for the grades to be less than 6 or 8 feet per mile. On the east side 30 feet to a mile is about the maximum gradient, while 5 feet or less is perhaps the average.

These conditions are due directly to the fact that the valley floor has been built up by the alluvial material eroded by the streams from the mountains east and west of the depression and deposited in it. The larger and more active streams build flatter but more extensive alluvial fans—the type that makes up the east-side slopes; the more erratic and torrential streams of smaller volume build the steeper and less extensive fans that constitute the west-side slopes.

[1]Hall, W. H., Physical data and statistics of California, pp. 396 et seq., State Eng. Dept. California, 1886.

GEOLOGIC OUTLINE.[1]

ROCKS OF THE BORDER OF THE VALLEY.

In simplest outline, the geology of the eastern border of San Joaquin Valley consists of the "Bedrock series" of granites and metamorphic sedimentary and igneous masses of pre-Cretaceous age, overlain at the north and south ends of the valley in an interrupted band occupying a zone of low relief between the Sierra proper and the valley proper by a series of Tertiary sediments, entirely unaltered and including beds as old as the Eocene, although the great body of the material seems to be Miocene or Pliocene in age. Between San Joaquin River and Portersville this zone of late sediments is missing, and the sands and gravels of the valley proper lie upon the flanks of the granites and the metamorphic complex. Because of this hiatus the east-side Tertiary is separated into two bodies, of which the northern extends from Fresno River nearly to the Cosumnes, and the southern, conveniently designated as the Bakersfield area, extends from Deer Creek to Cañada de las Uvas.

The northern area of Tertiary rocks, which is chiefly in the Milton-Merced regions, includes a lower, clayey series that has been called the Ione formation, a middle zone of andesitic sandstone, coarse volcanic breccias, and tuffaceous beds, and an upper gravelly series that is in places auriferous. This upper series usually occurs along the most westerly foothills and merges at many points with the gravels and soils of the valley floor.

The southern area consists of alternating beds of soft sandstone, clay, and gravel, the uppermost beds being coarse, like those of the northern area, and scarcely distinguishable in some places from the alluvium of the valley itself.

The geology of the western margin of the valley contrasts in many ways with that of the eastern border. The oldest rocks of the Mount Diablo Range—the easternmost of the coast ranges—comprise a series of altered igneous and sedimentary rocks of Jurassic (?) age known as the Franciscan formation, which extends along the axis of the range from a point southwest of Coalinga to San Francisco Bay. Overlying them on the valley side, but not continuously, is a series of sandstones, shales, and conglomerates of Cretaceous and earliest Tertiary (Eocene) age. Succeeding these in turn is a variable series, locally of great thickness and usually but not always present in some of its members, representing the middle and upper Tertiary. These rocks, like the older sediments beneath them, are sandstones, shales, and conglomerates, but usually they are less firmly indurated than the Eocene and Cretaceous rocks. They overlie the latter unconformably and contain many unconformities within themselves, with a

[1] Abstract from a manuscript by H. R. Johnson, on the geology of the borders of San Joaquin Valley.

resulting variability in thickness and irregularity in extent of individual beds. This series contains the siliceous shales generally spoken of in literature as the Monterey, besides a great variety and abundance of sandstones and conglomerates. Toward the top of the series are beds that clearly represent fresh water or subaerial deposition, undoubtedly much like that which is now taking place in Tulare Lake and in the west-side alluvial fans. As a whole the sedimentary series dips toward the valley, although interruptions like the anticline of the Kettleman and McKittrick hills in places vary the prevailing monoclinal dips. In general the structures of the valley border are more complex at the south end than along the middle portion and at the north.

The valley as a whole is a great structural trough and appears to have been such a basin since well back in Tertiary time. Since it assumed its general troughlike form, gradual subsidence, perhaps interrupted by periods of uplift, has continued and has been accompanied by deposition alternating at least along what is now its western border with intervals of erosion. This interrupted but on the whole continuous deposition seems to have been marine during the early and middle Tertiary; but during the later Tertiary and Pleistocene, when presumably the valley had been at least roughly outlined by the growth of the Coast Ranges, fresh-water and terrestrial conditions became more and more predominant, until the relations of land and sea, of rivers and lakes, of coast line and interior, of mountain and valley, as they exist now, were gradually evolved. As these conditions developed, the ancestors of the present rivers probably brought to the salt and fresh water bodies that occupied the present site of the valley and its borders, or, in the latest phases of the development, to the land surface itself, the clays, sands, gravels, and alluvium that subsequently consolidated into the shales, sandstones, and conglomerates of the late Tertiary and Pleistocene series, just as the present rivers are supplying the alluvium that is even now accumulating over the valley floor.

The very latest of these accumulations are the sand and silt and gravel beds penetrated by the driller in his explorations for water throughout the valley. They are like the early folded sandstones, shales, and conglomerates exposed along the flanks of the valley, except that they are generally finer, and are not yet consolidated or disturbed. The greater part, perhaps all of them, accumulated as stream wash on the valley surface or in interior lakes like the present Tulare Lake, but a proportion of the older sediment that is greater as we delve farther back into the geologic past accumulated in the sea or in salt bays having free connection with the sea. It is these very latest geologic deposits, saturated below the ground-water level by

the fresh water supplied chiefly by the Sierran streams, that constitute the reservoirs drawn upon by the wells, whether flowing or pumped, throughout the valley.

The chemical composition of the ground waters, as well as their occurrence and accessibility, is related to the geology. Where the valley alluvium is derived from the Cretaceous and Tertiary beds of the coast ranges, rich in gypsum and other readily soluble minerals, the ground waters contain large quantities of the salts. Where, on the other hand, the alluvium is derived from the granites and metamorphic rocks of the Sierra, whose potassium, sodium, and calcium compounds are in the form of difficultly soluble silicates, the ground waters under ordinary conditions contain very little of these salts.

Obviously if the sands and gravels through which the ground waters percolate were deposited under such conditions that salts were deposited with them, as in the salt water of the sea or of bays like San Francisco Bay, or in interior lakes that are saline through evaporation, as is true of Tulare Lake, then the ground waters themselves will quickly become saline, although when they leave the mountains as surface waters, before their absorption by the alluvial fans, they may be as pure natural waters as are known in the world.

ORIGIN OF THE PRESENT SURFACE OF THE VALLEY.

The lowland through the heart of California known as the Great Valley, whose origin as a depression appears, in accordance with the facts just outlined, to date well back into Tertiary time, owes its actual surface to more recent action and to more obvious agents. That surface is, in brief, a combination of the surfaces of a great number of alluvial fans, originating at the mouths of the canyons through which the tributary streams discharge from the mountains into the valley.

Each stream that enters the valley brings with it from the mountains a greater or a smaller quantity of sand, gravel, or bowlders. All or a part of this burden is deposited in the valley, and the deposit constitutes the alluvial fan of that particular stream. The apex of each fan is the mouth of the stream canyon. From this apex it broadens and flattens until it coalesces at its periphery with other fans. The stream that built it usually spreads delta-wise over it, discharging through a number of diverging channels into the trough of the valley. As a rule these spreading distributaries flow upon the surface of the fan, but some of the major streams from the San Joaquin northward are incised into the valley floor in trenches 100 feet or less in depth. This must be due to special conditions, such as recent change in volume of stream flow or in elevation of the land relative to the sea—conditions not yet understood.

The fans of different portions of the valley indicate by their mass and form the conditions of volume and distribution of rainfall under which they originated. The west-side fans, particularly those in the middle of the valley and near its southern end, are steep and symmetrical, forms characteristic of areas of low rainfall very irregularly distributed. The east-side fans are of much greater mass and lower slope because the rivers that built them have a greater flow of somewhat less irregular character. The Kern River fan has grown westward against the McKittrick hills until it has isolated the Buena Vista basin south of it. Before dams had been built, interfering with the natural conditions here, a shallow lake occupied the present site of Buena Vista reservoir and the old bed of Kern Lake, and during seasons of unusual rainfall there was overflow northward toward Tulare Lake. The basin occupied by Tulare Lake is likewise due to the aridity of the valley and the consequent development of Kings River and Los Gatos Creek fans. South of the low, broad ridge due to the coalescing of these two fans is the Tulare basin, in which a part of the surplus water of the streams south of it accumulates. As a consequence of the flatness of this basin and the very erratic character of the supply that reaches it, the lake fluctuates widely in area during a series of years.

Northward from Tulare Lake basin the discharge of the streams is sufficiently great and sufficiently constant to prevent the formation of delta-dams like those formed by Kings River and Los Gatos Creek fans, and an open channel is maintained from the San Joaquin northward to Suisun Bay.

Along the lower course of the San Joaquin, conditions resemble those in Sacramento Valley—that is, they are the conditions usual along rivers draining humid rather than arid regions. Large areas are subject to regular annual inundation during the spring floods or are protected from this inundation only by artificial levees. The greater part of the water that inundates this area is supplied by the Sacramento system, but the greatest overflow occurs when the floods appear in the two systems at the same time.

The essential fact as to the present valley surface is that it is a direct result of stream action. It has everywhere been built up by deposition from the streams or from the fluctuating lakes that are themselves dependent upon the streams; and it is formed of materials brought by the streams from the mountainous portions of their drainage basins where they are eroding instead of depositing. Throughout the south end of the valley its surface is a combination of alluvial fan surfaces; at the north end of the valley these fans, less strikingly and typically developed because of the greater precipitation there, still predominate along the valley borders, while the center of the valley is a flood plain of the usual type.

SOILS.

As the valley surface has been molded by stream action into its present form, so the soils of the valley represent deposition by the rivers of materials washed out of the mountains from which they drain. This soil is modified in various ways after the streams have deposited it—by disintegration of the rock particles where the streams have left them, by the mingling of the products of vegetal decay where vegetation is abundant, or by chemical processes in place, such as the formation of hardpans or the accumulation of alkalies; but the soil foundation, so to speak, reflects pretty closely the type of rock outcropping in the drainage basin of the stream on whose delta the particular soils are found.

For example, the soils of the deltas of Kern and Kings rivers are in large part of granitic derivation, because granitic rocks form the greater part of the mountain drainage basin of each of these rivers. Their coarseness and the distribution of the coarse and fine phases are to a certain extent matters of accident, due to the location of present or past channels of the streams across their deltas; but in steep alluvial fans the coarser and more bowldery soils occur nearer the mountains. In the fans of those east-side streams from the Merced northward, whose lower courses at least are cut through late Tertiary formations containing a large percentage of lavas and derived products, other types of soil result.

The west-side streams, draining mountains practically free from granites and similar rocks but with soft serpentines, shales, and sandstones, deposit fragments of those rocks in their alluvial fans, and the result is a soil type entirely different from that of the east side and south end of the valley. These shale, clay, serpentine, and sandstone fragments disintegrate much more quickly than the granitic sands that contain large proportions of such resistant minerals as quartz and feldspar, and the result is the mellow, loamy soil with its fragments of siliceous shale that makes much of the west slope of the valley and is so productive whenever water can be applied to it.

Soil of another general class occurs at a few localities along the east side of the valley. This soil is not of alluvial fan origin, brought into the valley by the streams from the surrounding mountains, but is due to decay in place of the rocks underlying the particular area where it occurs. Soils of this class are found northeast of Fresno beyond Clovis, and in some of the coves like Clark Valley north of Reedley, and perhaps in other foothill valleys in the Portersville-Lindsay district. Some of the rolling wheat lands found in a zone along the eastern border of Stanislaus and Merced counties may also be regarded as derived from the decay of rock in place rather than from inwashed alluvial fan material, but as the rock is itself a late

Tertiary sediment differing but little from the alluvial fan material of the same area, the classification of the soils as residual rather than colluvial has no practical significance.

Another type of soil is neither more nor less than fine beach sand. This type is best developed in a zone surrounding Tulare Lake, and it represents the shore lines of that water body when it contained much more water than at present. In places this sand has been reworked by the wind—blown into inconspicuous dunes, as in the "Sand Ridge" near the Kings-Kern county line.

Finally, there are the soils of the "tule lands" and the "islands," the areas subject to overflow particularly along the lower course of the San Joaquin and its tributaries, but present, although less extensively developed, in other areas. These lands are black loams or adobes or impure peats, and when reclaimed are particularly adapted to certain classes of crops.

The Bureau of Soils of the Department of Agriculture has made detailed surveys of certain areas in San Joaquin Valley as the beginning of a general soil mapping of the entire valley. The sheets at present available cover areas about Stockton, Modesto, Turlock, Madera, Fresno, Hanford, Portersville, and Bakersfield. In the text of the reports and in the maps that accompany them, the soils are classified in great detail on a physical basis, and by a proper study of this classification the geologic origin of most of the soils may be traced.

Another task undertaken by the Bureau of Soils, of even greater immediate value, is the mapping of the alkalies.[1] This work is designed to afford suggestions as to the management and reclamation of alkali soils and prevention of the rise of the alkalies. When it has been completed for the entire valley it will be of great service in preventing sales of worthless lands to purchasers who buy in good faith with the idea of establishing homes. Many sales of this kind have been made in the valley, and any work that will tend to reduce their number is to be welcomed.

SURFACE WATERS.

The streams of San Joaquin Valley and their characteristics have been referred to incidentally in the preceding pages. These characteristics depend upon the physical geography of south-central California and the control which it exerts over climate. All of the perennial and important streams flow from the Sierra.

Precipitation within the Sierra district depends upon altitude, latitude, and longitude. Up to a certain limit precipitation increases

[1] Mackie, W. W., Reclamation of white-ash land affected with alkali at Fresno, California: U. S. Dept. Agr. Bur. Soils Bull. 42, 1907.

with increase of altitude; beyond that limit, which at the crossing of the Central Pacific is at Cisco, 6,000 feet above sea and 1,000 feet below the summit, precipitation decreases. Rainfall decreases also southward along the summit of the Sierra as well as in the valleys; and in those parts of the range, principally its southern portion, where altitude does not increase regularly from the western toward the eastern margin, so that the effect of longitude is not obscured by that of altitude, vegetation indicates less rainfall as the desert border of the range is approached.

Under these conditions, therefore, it is evident that the greatest discharge per unit of area will come from those streams with the greater proportion of their drainage basins farthest north, in the high part of the Sierra but west of the summit.

The following table has been compiled from tables of discharge in United States Geological Survey Water-Supply Papers 298 and 299 and unpublished records for July, August, and September, 1912, and shows the yearly discharge in second-feet per square mile for certain rivers draining the western slope of the Sierra. Values are for the year ending September 30.

TABLE 1.—*Yearly discharge in second-feet per square mile of certain California rivers.*

	1905–6	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12
Kern River near Bakersfield	1.08	....	....	1.02	0.435	0.590	0.247
Tule River at Portersville	1.73	0.805	0.423	1.50	.608	.631	.258
Kaweah River near Three Rivers	2.88	1.58	.670	2.13	.925	1.45	.548
Kings River near Sanger	3.05	2.18	.819	2.23	1.41	2.24	.764
San Joaquin River near Friant	....	....	.960	2.45	1.71	3.00	.878
Merced River near Merced Falls	2.58	2.70	.656	1.89	1.35	2.69	.651
Tuolumne River at Lagrange	3.24	3.45	.987	2.45	1.91	3.15	.967
Stanislaus River at Knights Ferry	3.51	4.13	.876	2.81	2.01	3.43	.863
Calaveras River at Jenny Lind	....	....	....	[a] 1.80	.667	2.34	.219
Mokelumne River near Clements	2.90	3.61	1.03	2.48	1.95	3.30	.843
Cosumnes River at Michigan Bar	....	....	.396	1.70	1.22	2.31	.356
American River at Fairoaks	3.45	4.15	1.05	3.32	2.56	3.98	.911
Bear River at Van Trent	2.95	3.84	.988	2.78	1.35	2.70	.460
Yuba River near Smartsville	4.11	5.10	1.80	4.41	3.03	4.00	1.28
Feather River at Oroville	2.55	3.56	1.32	2.81	1.71	2.66	.791

[a] 11 months, October missing.

An examination of the above table shows that there is a general tendency toward increase in the discharge per square mile northward from the Kern to the Feather. Except Kern, Merced, Calaveras, Cosumnes, Bear, and Feather rivers the streams occupy comparable positions on the western slope of the Sierra and drain the areas of maximum precipitation for their respective latitudes. The rather regular increase northward may therefore be assigned with confidence to the effect of latitude on precipitation. The drainage basins of both the Feather and the Kern extend into the very eastern part of the Sierra beyond the zone of maximum precipitation, and the inferiority of run-off from their basins as compared with that of neighboring streams may be assigned, in part at least, to the effect of

longitude—that is, their basins extend so far east as to be measurably affected by desert conditions. Altitude may also be a factor since the Feather and the Kern drain portions of the range which are not so high as some of the intermediate areas. The deficiencies of Merced, Calaveras, Cosumnes, and Bear rivers may be in part ascribed to altitude and in part to longitude as the major portion of their areas does not extend to the summit of the range. The discharge of the principal east-side streams and the areas drained by each are summarized in the following table, compiled from the records of the State Engineering Department of California and from those of the United States Geological Survey.

The number of years of observations from which the average discharge was determined is also given. As the length of these records varies from four to twenty-two years it is obvious that they differ in value; but on the whole they supply a concrete indication of the average amount of water discharged into the San Joaquin Valley annually by its chief streams.

TABLE 2.—*Mean annual run-off of streams from east side of San Joaquin Valley.*

Stream.	Years of record.	Length of record.	Drainage area.	Mean annual run-off.	Second-feet per square mile.
		Years.	*Square miles.*	*Acre-feet.*	
Kern and Tulare Lake basins:					
Kern River near Bakersfield	1879–1882, 1893–1906, 1908–1912	22	2,345	695,000	0.409
Tule River near Portersville	1901–1912	11	266	137,000	.711
Kaweah River near Three Rivers.	1903–1912	9	520	506,000	1.34
Kings River near Sanger	1895–1912	17	1,740	1,940,000	1.54
San Joaquin River proper:					
San Joaquin River near Friant	1878–1882, 1896–1901, 1907–1913	15	1,640	1,944,000	1.64
Chowchilla Creek near Buchanan.	1878–1884	6	268	111,000	.571
Mariposa Creek at foothills	1878–1884	6	122	33,100	.375
Bear Creek at foothills	1878–1884	6	166	47,200	.393
Merced River near Merced Falls.	1878–1882, 1901–1912	15	1,090	1,200,000	1.52
Tuolumne River near Lagrange.	1878–1882, 1895–1913	22	1,548	2,050,000	1.18
Stanislaus River at Knights Ferry.	1878–1882, 1895–1900, 1903–1913	19	1,035	1,390,000	1.86
Calaveras River at Jenny Lind	1908–1912	4	395	351,000	1.23
Mokelumne River near Clements	1878–1881, 1901, 1903–1913	14	631	988,000	2.16
Dry or Jackson Creek at foothills.	1878–1884	6	283	172,000	.841
Cosumnes River at Michigan Bar.	1907–1913	6	536	400,000	1.03
Total			12,585	11,964,300	

NOTE.—Compiled from Water-Supply Paper 299. The records for 1878 to 1884 were collected by the State Engineering Department of California; many of them, however, were estimates based on run-off of adjacent streams. These estimated records have been omitted from the above compilation when records for other years were available.

The high-water period of the Sierra streams comes during the late spring and early summer months, when the snow accumulated in the winter is melting most rapidly from the mountains; the low-water flow comes during the late summer and fall months after the snows are gone and before the winter rains have begun. These characteristics are illustrated in the following table of monthly discharge of

Kings River for 1906, as determined by the United States Geological Survey:[1]

TABLE 3.—*Monthly discharge of Kings River near Sanger, 1906.*

Month.	Discharge in second-feet.			Total in acre-feet.
	Maximum.	Minimum.	Mean.	
January	25,500	205	2,360	144,000
February	2,150	792	1,150	63,900
March	21,000	1,220	5,240	322,000
April	7,760	2,960	4,720	281,000
May	16,800	3,930	10,700	658,000
June	26,600	8,320	17,100	1,020,000
July	22,400	8,180	16,300	1,000,000
August	7,900	1,870	4,300	264,000
September	2,020	682	1,120	66,600
October	682	385	516	31,700
November	610	330	397	23,600
December	2,230	330	700	43,000

Each of the major streams discharges from the mountains upon the eastern edge of the valley in a single channel, but after reaching the valley it usually divides into a number of branches, thus spreading over its delta. This characteristic is most marked in the streams that flow into the southern end of the valley, for many of the northern tributaries are incised in the valley floor and are thus confined between definite banks. This distribution is much more pronounced during the high-water period of early summer than at other seasons of the year. A main channel of sufficient capacity to carry the low-water flow proves inadequate during the flood period, and there is then overflow into the numerous subsidiary channels.

The natural habit of all of the main streams has of course been extensively modified by irrigation. Canal systems now take from the channels practically all of the low-water flow and an important percentage of the maximum early summer flow. These systems have been described by Grunsky.[2]

The west-side streams are practically negligible as factors in the San Joaquin Valley water supply. Only a few of them are perennial, and the late summer flow of these is so slight that a few acres at most can be irrigated by their use. A trifling amount of irrigation of this type is accomplished by utilizing the waters from Los Gatos Creek, Cantua Creek, and others.

[1] U. S. Geol. Survey Water-Supply Paper 213, p. 159, 1907.

[2] Grunsky, C. E., U. S. Geol. Survey Water-Supply Papers 17, 18, and 19. These papers are no longer available for distribution, but they may be consulted in libraries.

OCCURRENCE AND UTILIZATION OF GROUND WATER.

By W. C. Mendenhall.

ORIGIN OF THE GROUND WATER.

The ground water of San Joaquin Valley has precisely the same origin as its surface water—namely, the rainfall and snowfall in the drainage basins tributary to the valley. It is in reality simply that portion of the surface water that sinks into the sands and gravels of the valley floor and makes the rest of its journey seaward by slow percolation through the pores between the sand grains.

One of three things happens to the water that reaches the earth's surface as precipitation: (1) It returns directly to the air by evaporation from plant, soil, or water surfaces; or (2) it flows to the sea in surface streams; or (3) it sinks into the ground and joins the body of water that saturates the soil particles below the ground-water level. It is with the latter part of the precipitation on the nearly 32,000 square miles of area included in San Joaquin Valley and the mountain watershed tributary to it that we have to deal.

In the outline of the geologic history of the valley it has been pointed out that its entire surface is made up of the surfaces of contiguous alluvial fans, and that the valley is underlain to a depth that can not be determined accurately, but that doubtless runs into thousands of feet, by porous, unconsolidated, alluvial-fan material, mingled, in some areas, with lake deposits. This material has been transported from the mountains to the valley by the agency of running water. Many times its own volume of water has passed through and over it in the course of its removal from the mountains to the valley. It was deposited by and in water and has been more or less continuously saturated ever since.

A large but quite undeterminable portion of the run-off from the mountains each year sinks and joins the ground water. Of the 3,300,000 acre-feet discharged annually into the valley south of the Kings River-San Joaquin divide, only the small portion that spills northward from Kings River itself reaches the sea over the surface, because there has been no outflow from Tulare Lake for forty years. The greater part evaporates or sinks to join the underground supply. Northward from Kings River the surface waters are greater in volume than south of it and serve effectually to keep the sands and gravels beneath them saturated.

UNDERGROUND CIRCULATION.

Ground waters near the surface usually move slowly in the direction of the surface slope and at rates that vary with the gradient of the slope and the coarseness of the material through which they percolate. The freedom of the outlet by which they escape is also important. They may be ponded by a restricted outlet just as surface waters may. Measurements of rates of ground-water movements in San Joaquin Valley are not available, but facts stated in the following paragraph indicate pretty plainly the conditions that probably prevail:

1. The alluvial fans that make up the valley floor are generally of low slope and fine material. The fans of the Cañada de las Uvas and of San Emigdio Creek, at the south end of the valley, and of Pala Prieta and Los Gatos creeks on the west side are exceptions; but the streams that have produced them contribute so small a proportion of the ground waters that they may be disregarded. 2. The general slope of the lowest line of the valley, from the south to the north, is not only not continuous, in that it is interrupted by ridges like that north of the Tulare basin, but it averages only about 1 foot to the mile, a very low gradient for a semiarid region. 3. The wells drilled throughout the valley prove that the sediments underlying it are all fine. 4. The surface outlet of the San Joaquin and Sacramento drainage is by way of Suisun Bay and the straits of Carquinez to San Francisco Bay; but the straits are restricted, and it is not probable that bedrock lies far beneath the surface in their vicinity. In short, there is no adequate outlet for the ground waters of the Great Valley, which is canoe-shaped, with only a notch in the rim at the straits through which the surface waters spill. All these conditions favor slow movement of the ground waters about the borders and at the ends of the valley, with their practical stagnation along the lower San Joaquin because there is no adequate outlet for them there. To be sure, capillarity and evaporation afford some slight escape for the ground waters as they approach the surface in their slow movement along the valley axis. The great alkali areas of the west slope and of the valley trough indicate escape of ground waters, because it is by this escape that the alkalies are concentrated at the surface; but the outlet provided in this way is of slight consequence when compared with the total body of ground waters.

The belief that there is little movement in the subsurface waters of the lower San Joaquin is strengthened by a consideration of their chemical characteristics. Some of the ground waters of the upper deltas of the east side are among the purest waters of this type known, while those from the shallow flowing wells of the bottom of Tulare Lake and from the deeper wells of the north end of the valley are so

heavily charged with mineral matter as not to be potable or suitable for irrigation purposes. Ground waters dissolve the soluble minerals from the rock fragments—the clay, sand, or gravel particles with which they are in contact. The amount thus dissolved depends upon the chemical combinations in which the minerals exist, some being much more soluble than others, and upon the length of time during which the waters are in contact with them. In general, the alkalies in the sands and gravels of the east side are in the most resistant form, the silicates of the granitic débris from the Sierra; the alkalies of the sands and gravels of the west side are in less resistant form, the sulphates and carbonates of the Cretaceous and Tertiary shales and sandstones; hence the ground waters of the high parts of the east slopes of the valley, which move with comparative rapidity, are much purer than the waters from similar situations on the west side. Furthermore, the volume of water poured out upon the east-side fans is many times greater than that discharged upon the west side, so that the alkalies dissolved are greatly diluted. But down in the trough of the valley, especially near its north end, the ground waters contain a much larger percentage of salts, even than those of the west side. If there were rapid circulation of ground waters here, this condition should not exist, for the dissolved salts should be gradually carried out. The fact that the waters are highly mineralized is regarded then as additional evidence of sluggish circulation, or perhaps practical stagnation.

QUANTITY OF GROUND WATER.

Little need be said of the quantity of ground water in the valley, for two reasons: The first is that although it is clear that the quantity is enormous, it is not possible to estimate it with any exactness; the second is that the actual quantity is not of so much importance in its use as its accessibility and the rapidity with which it is restored when withdrawn.

The area of the valley is about 11,500 square miles. The depth of the sands and gravels which are saturated with the ground waters is probably not less than a mile at the maximum, and may be much more. The average depth is equally unknown, but wells 1,000 or 2,000 feet deep, or even more, that are scattered throughout the valley, do not reach the bottom of the unconsolidated sands and gravels; so it may safely be assumed to be one-quarter of a mile and more. At this depth, nearly 3,000 cubic miles of sands, gravels, and clays are saturated with ground water, and if the porosity is 20 per cent the conclusion is reached that 600 cubic miles of water underlies the valley—certainly both a sufficiently conservative and a sufficiently startling estimate. But this includes waters of all qualities, some not usable, and some lying at great depths and not accessible.

ACCESSIBILITY AND AVAILABILITY OF GROUND WATER.

One of the most important elements in the cost of ground water, of course, is its accessibility, by which is generally meant the depth at which it stands beneath the surface; but the depth of boring necessary to develop it and, if pumped, the amount that it is drawn down when the pumps are in operation are also important elements.

The cheapest waters in general are those that flow out at the surface, even though deep wells may be necessary to develop them and the initial cost may therefore be great. But these waters may not always be most available, because they are to be had only in the lower parts of the valley, where, because of climatic conditions and alkalinity of soil, many of the lands are less valuable than those farther up the slopes. Generally speaking, about the borders of the valley the ground waters lie at the shallowest depths in the deltas and at the greatest depths in the interareas. The flood channels and the irrigation ditches are the lines along which recharge of the ground waters is effected; hence in their vicinity the ground-water level lies near the surface and the pumping lift is at a minimum.

Beneath the higher parts of the west-side slopes, unfortunately, where water is most needed, it is not accessible. The conditions here illustrate well the dependence of the ground water upon local surface supply. Surface run-off is most limited in this area and the ground water lies at too great depth for profitable utilization.

DEVELOPMENT OF GROUND WATER.

The development of ground water in the valley is as yet in its infancy. It does not compare in intensity with that in southern California, where, with an irrigated district of perhaps a quarter of a million acres, there are nearly 3,000 flowing wells, costing about $675,000 and yielding nearly 200 cubic feet of water per second, and at least 1,500 pumping plants in which $2,500,000 or more is invested, by which an average of nearly 300 cubic feet per second of water is produced. Other minor wells increase the investment, but add little to the product. The total estimated investment in the development of ground water, exclusive of the distribution systems, is about $5,000,000 in this restricted district and the water produced is approximately 500 cubic feet per second. For comparison with this development south of the Tehachapi, the following estimates have been prepared from the records obtained by the United States Geological Survey in 1905–1907 to indicate the relatively meager development in San Joaquin Valley at that time.

TABLE 4.—*Ground-water development in San Joaquin Valley in 1906.*

County.	Number of artesian wells.	Estimated cost.	Estimated yield.	Number of pumping plants.	Estimated cost, well and plant.	Estimated capacity.	Estimated output (one-sixth capacity).	Total cost.	Total yield.
			Sec.-ft.			*Sec.-ft.*			*Sec.-ft.*
Kern	112	$161,400	73.46	104	$138,632	255.84	42.64	$300,032	116.1
Tulare	124	189,968	23.31	191	244,098	162.72	[a] 54.24	434,066	77.55
Kings	77	112,959	19.3	3	1,530	1.34	.24	114,489	19.54
Fresno	40	40,000	7.5	28	....	30	5	....	12.50
Madera	31	13,237	7.81	17	44,931	40.8	6.8	58,168	14.61
Merced	133	48,013	7.95	43	46,700	40.93	6.82	94,713	14.77
Stanislaus	5	3,830	1	9	....	8.35	1.39	....	2.39
San Joaquin	......	....	....	202	123,836	250	41.67	....	41.67
	522	569,407	140.33	597	599,727	759.98	158.80	1,001,468	299.13

[a] One-third capacity.

The data on which these estimates were based were neither so complete nor so satisfactory as those used in southern California, and therefore the conclusions must be regarded as suggestive rather than as accurate in detail. As an example of one of the weak points in the estimates, attention may be called to the column in which the output of the pumping plants is recorded. Generally these plants are used in the irrigation of alfalfa or of garden products. Some of them are independent sources of water; others are auxiliary to gravity waters and are used only when the latter are not available; some are in the southern part of the valley, where the rainfall is less than 5 inches; others are in the northern part of the valley, where the rainfall is more than twice as heavy, and where on this account less water need be applied artificially. Of course the pumps are not in constant operation anywhere, but the percentage of the year that they are run varies with local conditions. No exact estimate of this percentage can be made, but it has been assumed in the estimates that the pumps are operated the equivalent of two months continuously, hence, that their output for the year is one-sixth of what it would be were they in constant operation. This estimate is more likely to be too high than too low. In one county, Tulare, which includes the Portersville, Exeter, and Lindsay citrus districts, a larger factor is used. Most of the pumps in this county are used for citrus irrigation, and it is assumed here that their output is one-third of what it would be were they in continuous operation. This estimate should not be excessive.

Accepting the estimates, then, as they are, we find that in San Joaquin Valley there were in 1905–6 between 500 and 600 flowing wells and a somewhat greater number of pumping plants, representing an investment between $1,000,000 and $1,500,000 and yielding in the neighborhood of 300 cubic feet per second. The number of wells then was about one-fourth that of southern California, the investment one-third, and the product about one-half, although the total irrigable

area of San Joaquin Valley is nearly 10 times that of the southern field and the ground waters available are probably in similar ratio. This comparison, even though the figures upon which it is based are not complete, gives a graphic idea of the development that may yet be accomplished in central California by the full use of the ground-water resources.

A later review of ground-water development and conditions has been prepared by S. T. Harding and Ralph D. Robertson.[1] Their conclusions, based largely on the data herein presented but supplemented by some later statistical information, may be quoted:

It is estimated in this report [Water-Supply Paper 222] that the ultimate amount of ground water developed may be 10 times that then developed in southern California, or 5,000 cubic feet per second. At that time [1905–6] about 300 cubic feet per second was being developed in the San Joaquin Valley. This has been more than doubled since. If 5,000 cubic feet per second is obtained for six months of the year, it will equal a total of 1,810,000 acre-feet, or approximately 15 per cent of the total mean annual discharge of the streams at the edge of the valley. Considering the generally open structure of the subsoils, the seepage of this amount or more can be considered as reasonable. Increase in gravity irrigation should increase the quantity reaching ground supplies. Ground water in sufficient quantity for irrigation can be obtained in all parts of the valley proper, except in the west-side areas. In the lower valley floor artesian flow can be secured, although this is not extensively used for irrigation. While the quantities available decrease and the lifts required increase from the valley trough to the east-side foothills, the value of the products which can be grown increases, so that the highest development may be found in the regions of smallest ground-water supply. As pumping for irrigation requires both an initial cost and an operation expense that are plainly evident to irrigators, the pumped water is generally used more economically than that from gravity canals. As a large portion of the water at present pumped is used to supplement the water received from canals, it is not reasonable to expect the area irrigated from ground water will be entirely additional to that irrigated from canals. While any estimate of the total possibilities of the ground supplies must be liable to much uncertainty, the area eventually irrigated wholly by this means will certainly be several times that at present supplied and may reach a total of 600,000 acres. While use of ground water will be rather general throughout the lower valley floor and east-side plains, the largest use will be where gravity supplies are the least accessible, as in San Joaquin County, or where supplemental pump supplies are the most profitable, as in the Fresno district.

VALUE OF THE WATERS FOR IRRIGATION.

Although the ground waters of the valley have been known and used in minor ways practically ever since its settlement, it is nevertheless true that the movement for their extensive utilization as sources of irrigation supply is a late phase of development, for many of the earlier attempts to make use of them resulted in failure.

Among the causes that have contributed to past failures may be mentioned: Application of the developed waters to poor lands;

[1] Harding, S. T., and Robertson, R. D., Irrigation resources of central California: California Conservation Comm. Rept. for 1912, pp. 172–240.

wasteful methods of application; dependence on the continuance of artesian flow; lack of adjustment to the greater cost of pumped waters as compared with that of the gravity waters upon which reliance has heretofore been placed; lack of intensive farming methods and of proper adaptation of crops to soil and locality; too large farm units; and, in a few cases, inadequate transportation facilities.

The most potent of all these causes has been the prevalence of the easy-going methods of the pioneer—the careless, wasteful habits that are a direct inheritance from the grazing and grain-raising period which has not yet passed from the valley. Land and such waters as are utilized have cost little heretofore in San Joaquin Valley, and things that cost little are lightly valued, no matter what their intrinsic worth. This spirit is fostered by the immense holdings of some of the larger companies. Few of these companies practice intensive cultivation, though their lands are among the best in the valley. Usually hay and grain are raised to feed through the dry season the stock that is in pasture during the grazing period. But although not as a rule intensely cultivated and by no means producing the maximum of food products or supporting the largest possible population, most of the large holdings are more carefully and successfully managed than the quarter section of the small farmer.

Despite all obstacles and discouragements, however, the use of ground waters is gradually extending. Special high-priced products like the citrus fruits of the Portersville-Lindsay district justify heavy expenditures for production, and ground water has long been successfully used in this section. The success of pumping water to great heights to irrigate the specially early citrus fruits of this region is fully demonstrated, the acreage devoted to these products is constantly extending, and the yield is increasing rapidly as groves planted recently approach maturity.

Irrigation by means of pumped ground water is also proving successful under the entirely different conditions that exist about Lathrop, Lodi, and Stockton, in San Joaquin County. Several hundred small pumping plants are in operation in this county, the greater number of which have been installed within a few years. By their use alfalfa, vineyards, and varied crops of fruits and vegetables are successfully grown. Windmills also are extensively used, often with auxiliary gas engines attached to the same well. The area in which this type of irrigation is practiced is closely settled, houses are neat, prosperous looking, and well cared for, the villages and cities which supply the country trade and market the products are flourishing, and altogether there is every evidence of successful endeavor and abundant prosperity.

Still other communities whose existence depends upon the utilization of ground waters are the recently established colonies in Kings,

Tulare, and Kern counties, of which the Corcoran settlement is a type. This particular locality is within the artesian basin, and a group of deep wells yield flowing waters which are utilized for all purposes. As a result, successful dairy farms have been established, sugar beets are raised, and a factory has been built for the manufacture of sugar from them.

It is thus evident that there is a gradual awakening to the value of the ground waters and their usability, although in many localities the advocate of the use of these waters is still met by the statement that they can not be developed and applied at a profit under agricultural conditions as they now exist. It is true that the pumped waters are more expensive than the ditch waters, whose cost as a rule is very low. The average cost of current for pumping the water used by the Kern County Land Co. near Bakersfield, with an average lift of 30 feet, is $1.29 per second-foot for 24 hours on the basis of a charge of 15 cents per horsepower per hour for electric current, whereas the charge for surface water in the same locality is 75 cents per second-foot for 24 hours—that is, the current for pumping the ground water costs more than the surface water. When it is remembered, however, that almost universally in San Joaquin Valley water is used in great excess, to the immediate and ultimate injury not only of the lands to which it is applied but of adjacent lands; that on many of the delta lands there is as yet but little intensive cultivation, and that therefore the margin of profit is low; that there is an important proportion of large holdings and absentee ownership dependent upon inefficient hired labor; and above all that, in the midst of the communities in which it is asserted that pumped waters can not be profitably used in agriculture individuals may generally be found who are using them with striking success; when all of these things are taken into consideration, it may be asserted with confidence that the greatest increase in the agricultural development in this valley in the future will be brought about by a utilization of the ground-water supplies, whose development has only begun and whose value is as yet but faintly realized.

It will probably be true in the future, as it has been in the past, that side by side with successful attempts at the utilization of ground waters will be unsuccessful attempts, and that the general movement for full realization upon this asset will be checked here and there by conspicuous failures widely advertised. This is a condition that always arises in any general advance. Each failure should teach its individual lesson as to a particular way *not* to undertake development or to apply water, and should not be interpreted as an argument against the usefulness of the resource under proper conditions, for the fundamental facts remain that ground waters exist beneath the floor of San Joaquin Valley in immense volume and that over wide areas they are of high quality and very accessible.

They are certain, therefore, to be widely used in the future, and by their use hundreds of thousands of acres now arid and unproductive will be brought to yield handsomely.

The development of the ground waters under the conditions that exist at present, when the chief argument against them is their cost as compared with that of the surface waters which have set the standard, should follow two or three lines.

In the first place, pumping plants in the higher parts of the delta lands should be used as adjuncts to insufficient gravity supplies. The supply of the gravity waters during the flood months of May, June, and July is from 2 or 3 to 15 or 20 times that available during the months of August, September, and October, when many crops are maturing. As a consequence many owners of late rights to gravity waters secure a portion of the flow during the early high-water period, but are left without it during the low-water period, when there is only sufficient to satisfy the earliest rights. Such owners often have enough gravity water for one or two early irrigations, but not more. Under present conditions, therefore, the maturing of late crops is a precarious matter with them, and they are confined practically to those products which will yield returns when irrigated only in the spring or early summer. This is a serious handicap, as it greatly limits the range of their agricultural activity and often condemns their land to idleness during half of the year. By the installation of pumping plants, to be operated only when gravity waters are not available, this handicap is removed, and yet the cost of irrigation is much less than where no surface waters are available and pumps must be operated continuously.

In the second place, in districts that have a market for garden products or for those special farm products whose value and yield justify some expense in their production, as sweet potatoes, celery, asparagus, or onions, the small land owner can well afford to install an individual pumping plant independent of surface supplies. The same method will be successful with crops that require only one or two irrigations a year, as, for example, some of the fancy varieties of grapes that are now raised so profitably in the northern part of the valley.

Another line to be followed in development is the utilization of flowing artesian waters. Along the axis of the valley is a zone with an area of about 4,300 square miles within which flowing waters are available. Over perhaps two-thirds of this area the flowing waters are sufficiently pure to be suitable for use in irrigation.

None of these lines along which it is suggested that ground waters may be used are experiments. Each has been followed successfully in some of the communities in the valley, although in other sections quite as favorably situated the investigator will be told that pumped

or flowing waters can not be used profitably. Communities, like individuals, fall into ruts, acquire bad habits, and lose the power of initiative. In this condition they may overlook or fail to utilize some of their most valuable assets.

In the course of this investigation nearly 4,000 wells in the valley have been examined and data collected as to depth, yield, cost, etc. Among them are many flowing wells. For most of the wells the data are incomplete, but from the records available the following averages have been determined:

TABLE 5.—*Average size, depth, yield, cost, etc., of flowing wells.*

County.	Number averaged.	Average diameter (inches).	Depth (feet).	Yield (miner's inches).[a]	Average cost.	Annual interest on cost at 8 per cent.	Interest charge per miner's inch per year.
Kern	10	10	621	53.3	$1,545	$123.60	$2.30
Kings	7	9	1,037	30	2,555	204.40	6.81
Tulare	32	8	745	26	1,711	136.88	5.26
Fresno	7	8	936	20	1,540	123.20	6.16
Merced	16	7	350	5½	470	37.60	6.84

[a] A California miner's inch equals 0.02 second-foot.

These averages are based upon the actual experience of owners of wells already drilled and flowing. They therefore have a definite value as a basis for estimating costs of artesian waters to be obtained as a result of future developments. They may be compared with the charge made on the Kern delta for gravity water, namely, 75 cents per second-foot for 24 hours, equivalent to $5.47 per miner's inch per annum.

In comment upon the table it is to be said that the Kern County average is too low, because it happens that among the wells for which sufficiently complete data exist for computing these averages there were one or two of exceptionally great yield that have unduly raised the average yield and reduced the cost, thereby giving a figure lower than that which will probably be realized in future development.

It must be remembered further that the figures are based on the assumption that the entire year's flow will be utilized. This assumption can be realized only by the construction of reservoirs in which the water will be stored during the nonirrigating season for use when wanted. Such construction will add to the cost and will reduce the supply in three ways: (1) By a reduction of flow because of the increased height of delivery necessary to discharge into a reservoir; (2) through loss by evaporation from the surface of the reservoir; (3) through loss by seepage from the reservoir.

The uncertainty as to the amount that will be delivered by any artesian well is another disturbing factor in making exact calcula-

tions. The area within which flowing waters are procurable has been outlined with approximate accuracy, but the yield of any well can be determined only after the well has been sunk and the necessary capital invested in it. Some of the wells used in computations have delivered much more than the average supply and so have yielded exceptionally cheap waters; others have delivered less than the average, and their waters are correspondingly expensive.

Another condition that must be realized is this: When the number of wells drawing from the artesian supply is greatly increased in any particular neighborhood, the wells interfere and the yield of each is lessened. When the maximum acreage is dependent on artesian flow under these conditions, the installation of pumping machinery may become necessary in order to insure the continuance of an adequate water supply.

As against these disadvantages, which have been rather fully outlined, as is essential in any frank and therefore useful discussion, are to be placed regularity and relative constancy of the supply and its availability at all times, as compared with the fluctuations of surface waters unavailable except during the flood season to any but the owners of the oldest rights. An added advantage where the landowner owns his well is his complete control over his water supply. He may irrigate when and how he will, and thus most economically, and is not dependent upon the adjustment of supply among a number of users from a common source.

QUALITY OF THE WATERS.

By R. B. Dole.

IMPORTANCE OF QUALITY.

The wide range in the mineral content and consequently in the usefulness of the ground waters of San Joaquin Valley makes it necessary to know their composition before undertaking water projects involving any considerable expenditure. Most of the surface run-off may be used indefinitely in irrigation without deleterious effect, and ground water nearly as good can be obtained in many parts of the region, while certain aquifers yield supplies abundant in quantity but so highly mineralized that they are poisonous to vegetation. In the estimation of the railroad locator the amount of dissolved solids throughout the entire area is such as to make the quality of the water supplies equal in importance to quantity. Softening plants are necessary on the west side, and railroads are obliged to haul water to several stations, where the available supplies are unfit for steaming. In further extension of railroads through some townships the difficulty of procuring supplies that can be rendered suitable for locomotives will doubtless make quality of water the determining factor in the location of tanks, stations, and roundhouses. The wineries, breweries, ice factories, and laundries also must have water of proper quality, and the establishment of paper mills, strawboard mills, starch factories, sugar works, and other water-consuming mills of industries closely related to modern farming will make the quality of this important raw material a still more pressing problem. At present the needs of irrigation turn attention to all possible sources, because the demands of intensive farming have so far exceeded the available surface supply that underground waters are largely utilized and are depended on exclusively in some districts. This rapidly increasing draft on the ground reservoirs will ultimately bring about complete utilization of all supplies that can be safely applied under careful supervision and improved methods of irrigation.

Study of the chemical characteristics of water in this region is particularly interesting because of the great variety of conditions that affect the mineral content. The east side of the valley, filled with alluvium derived from hard, difficultly soluble rocks and furnished with water from the granitics of the Sierra, yields supplies entirely distinct in composition from those of the alluvium of the west side, which has been washed down from the gypsiferous sedimentaries of

the Coast Range. The amount of rainfall decreases southward from that of the semihumid country around Suisun Bay to that of the arid region in lower Kern County, the average annual precipitation at Lodi being about 18 inches, at Fresno 9 inches, and at Bakersfield only 5 inches. Both ground and surface waters are affected in composition not only by this progressive decrease of precipitation from north to south but also by the equally apparent difference in the amount of water received by the two sides of the valley. As the total precipitation on the west slopes of the Sierra is much greater than that on the east side of the Coast Range the streams of the east side of the valley exceed those of the west side in size and number, and a proportionate difference in quantity of ground water is reflected in its composition. A relation between topography and quality is traceable in the low ridges of the deltas, which favor the deposition of salts by confining strong solutions in small basins, thus establishing tracts where wells yield highly mineralized water. Changes in mineral content due to irrigation are shown by dilution of normal water in some sections and accumulation of alkali in others. The influence of these conditions of climate, geology, and economic development on the composition of the mineral matter makes study of the water instructive and pleasurable, while the agricultural and industrial interests that are involved render the results of great immediate value.

SOURCES OF DATA.

Most of the conclusions regarding the quality of the ground waters are based on the results of 400 partial assays made by the writer during the fall of 1910. Information regarding the effect of the waters in irrigation, steaming, and other uses was obtained by visiting about 500 wells. The general plan of the field study was to travel back and forth across the axis of the valley and to test as many samples as possible from wells of different depths near what was clearly recognized as the critical area—that along the axial line. Though this scheme was generally successful wells sufficiently varied in depth could not be found in some localities, and the onset of the rainy season finally prevented the completion of studies in Kern County. Fifty samples of water were analyzed by Mr. F. M. Eaton, of San Francisco, in order to supply more complete information regarding certain sources and to afford a check on the field assays. In addition a few waters were analyzed by Mr. Walton Van Winkle. The locations of the waters that have been tested are shown in Plate II (in pocket).

The quality of the surface waters was so thoroughly investigated by Van Winkle and Eaton[1] that it was not necessary to make any further tests, and statements herein about the mineral content of the surface waters are based entirely on their work.

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[1] Van Winkle, Walton, and Eaton, F. M., The quality of the surface waters of California: U. S. Geol. Survey Water-Supply Paper 237, 1910.

Valuable knowledge regarding the composition of the ground waters is afforded by miscellaneous analyses performed at the agricultural experiment station of the University of California; as these analyses are in such form that it is not practicable to incorporate them in the general part of this report they are appended in a separate table. Special acknowledgment is due to Mr. Howard Stillman, engineer of tests, Southern Pacific Co., and to Mr. W. A. Powers, chief chemist of the Santa Fe Railway Co., for placing at the disposal of the Survey analyses of the water supplies along the rights of way of these railroads.

CONDITIONS OF COLLECTION OF SAMPLES.

Though the mineral content of water from shallow wells in humid regions is materially lessened by the dilution following heavy rainfall, an opposite effect is produced by similar rainfall in areas of low precipitation because the water in a humid region percolates downward through layers that have been deprived of their easily soluble matter by long-continued leaching, whereas the sinking water on arid land dissolves the alkali in the upper soil and carries more or less of it into the wells, which ordinarily draw their supplies from below the belt of concentrated alkali. As the dry soils in arid regions are either highly absorbent or impervious occasional light rains do not affect shallow wells, but long-continued transmission of such nearly pure water, such as occurs near canals and in dry watercourses, removes the soluble salts from the ground so that shallow wells in the immediate vicinity yield better water than those farther away. Deep wells are certainly affected by long-continued periods of drought or rainfall, but how soon, to what extent, and in what manner are problems for which there is only theoretical solution. Consequently, as the concentration of shallow-well waters in San Joaquin Valley might be changed by heavy rainfall the conditions of precipitation during the year in which the samples were taken may be noted.

TABLE 6.—*Inches of precipitation in San Joaquin Valley during 1910.*[1]

Station.	County.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Lodi	San Joaquin	2.35	1.76	2.53	0.15	0.02	Tr.	0.00	0.00	0.46	0.32	0.21	1.27	9.07
Farmington	do	3.24	2.26	3.70	.17	.05	0.00	.00	.00	.50	.38	.38	.94	11.62
Tracy	do	1.90	1.20	.....	.00	.00	.00	.00	.....	.....	.10	.05	.42	.....
Oakdale	Stanislaus	2.95	.83	3.28	.34	.06	.00	.00	.00	.29	.16	.39	.67	8.97
Denair	do	1.56	.55	3.00	.72	.01	.00	.00	.00	.20	.04	.04	.02	6.14
Newman	do	1.99	.28	2.60	.18	.00	.00	.00	.00	.52	.12	.19	.51	6.39
Le Grand	Merced	2.10	.48	1.88	.83	.00	.00	.20	.00	.30	.83	.73	.28	7.63
Los Banos	do	3.22	.30	2.03	.00	.....	.00	.00	.00	.25	.28	.26	.47	6.81
Storey	Madera	.67	.50	1.40	.49	.00	.00	.00	.00	.75	.80	.....	.26	.....
Fresno	Fresno	1.22	.21	1.28	.27	Tr.	Tr.	Tr.	.00	1.00	.45	.24	.21	4.88
Selma	do	2.00	.14	1.09	.35	.00	.00	.00	.00	1.50	.55	.33	.47	6.43
Hanford	Kings	2.40	.00	1.66	.....	.....	.00	.00	.00	.....	.31	.....	.....	.....
Portersville	Tulare	2.37	.22	1.96	.34	.00	.00	.04	.00	.14	.64	.36	1.03	7.10
Angiola	do	.66	.00	1.45	.....	.00	.00	.00	.00	.88	.57	.30	.60	.....
Wasco	Kern	1.79	.00	.68	.16	.00	.00	.00	.00	.85	.25	.19	.70	4.62
Bakersfield	do	1.15	.22	1.20	.00	.00	.00	.00	.00	.00	.83	1.37	.54	5.31

[1] Compiled from the Monthly Weather Review, U. S. Dept. Agr., Weather Bureau, 1910.

The total precipitation in the valley for the year was considerably less than the average during the preceding 10 years, the northern stations showing greater deficiency than the southern ones. According to Table 6, in which the records of 16 selected stations are arranged in geographical order from north to south, one-half to three-fourths of the rain fell during the first four months of the year. There was practically no rain at all between April and the middle of September, and all the streams throughout the valley were markedly low during that period. Unusually early and heavy rainfall took place September 14, 15, and 16, but as the ground had been so long without rain the effect of the influx on the quality of the ground water was probably inappreciable. Some slight showers occurred during October, but they were barely sufficient to dampen the surface of the ground and are negligible. More rain fell during November, but the field work had been carried by that time below Fresno into the semiarid region where the precipitation was proportionately light. The stream discharges were little affected by the November rains. The rainfall during December was far below normal, though the showers throughout Kern County were heavy enough to make the ground muddy. Field work was discontinued December 6, but a few samples, especially from deep wells in Fresno County, were collected the middle of December. Evidently, therefore, the samples were collected during or after the dry season before the ground could be affected by winter rains, and in a year of exceptionally low precipitation; consequently the mineral content of the waters may be considered to be normal. The greatest deviations from what may be looked upon as normal were found in waters from shallow wells near stream beds or flooded irrigation ditches, but such conditions could easily be recognized, and they have been noted in the detailed descriptions.

METHODS OF EXAMINATION.

FIELD ASSAY.

As the limited time and funds for the work prohibited complete analysis of all the samples and as such analyses of only a few waters could not be typical of waters over large areas, it was decided to test a great many waters as nearly correct in the field as such work can be done and to amplify and corroborate these data by a few laboratory analyses. The methods of assay described by Leighton [1] were employed in the field work, determinations being made of total hardness, and the carbonate, bicarbonate, sulphate, and chloride radicles. Color also was estimated in a few waters.

[1] Leighton, M. O., Field assay of water: U. S. Geol. Survey Water-Supply Paper 151, 1905.

CARBONATE AND BICARBONATE.

For the carbonate test 10 drops of a 1 per cent solution of phenolphthalein was added to 100 cubic centimeters of the water in a glazed white porcelain mortar, and the solution was then titrated with tablets of sodium acid sulphate, each of which was equivalent to about 1 milligram of carbonate (CO_3). Few waters contained normal carbonate; consequently a qualitative test with the indicator was sufficient to show their absence. Quarters of tablets, made by slicing with a knife, were used for more accurate estimation. Some tablets were then dissolved in a fresh portion of water to which 2 drops of a one-tenth per cent solution of methyl orange had been added, and the mixture was titrated with the water to an alkaline reaction. The amount of bicarbonate was computed by the formula

$$x=\frac{1000nA}{W}-2B$$

in which W = amount of water in cubic centimeters, A = the value of 1 tablet in milligrams of HCO_3, n = the number of tablets, x = parts per million of HCO_3, and B = parts per million of CO_3 as determined by the previous test.

CHLORINE.

A measured amount of the water, to which 5 drops of a 5 per cent solution of potassium chromate had been added, was titrated in the mortar with tablets containing silver nitrate, which were crushed and triturated by a pestle. The content of chlorine in parts per million can be calculated from the number and the standard of the tablets and the amount of water. Two strengths of tablets were used, one having an equivalent of about 1 milligram and the other about 10 milligrams of chlorine. Chlorines less than 300 parts were estimated in 50 cubic centimeters of water with the weaker tablets cut in quarters. Titration of greater amounts was commenced with the stronger tablets, and waters containing more than 2,000 parts per million of chlorine were diluted with distilled water before titration.

SULPHATE.

For estimation of sulphate 100 cubic centimeters of the water was slightly acidulated with hydrochloric acid (1—1), about 1 gram of moderately coarse crystals of barium chloride was added, and the cold mixture was vigorously shaken until the crystals were completely dissolved. This treatment precipitates barium sulphate in a finely divided state, and imparts to the liquid a turbidity the degree of which is proportional to the amount of sulphate and can be determined in the turbidimeter. This instrument consists essentially

of a glass tube inclosed in an open-bottomed brass tube suspended by a large-headed tripod over a standard candle, whose flame is kept automatically 3 inches from the bottom of the glass tube. The latter is graduated in millimeters from bottom to top in one scale and in cubic centimeters in another, so that it serves both as a depth measure for turbidity readings and as a graduate for general use. The liquid containing the precipitate of barium sulphate, after being thoroughly agitated, was poured into the graduated tube until the image of the flame disappeared. The depth in millimeters of the liquid in the tube was then read across the bottom of the meniscus, and the corresponding amount of the sulphate radicle (SO_4) was found by reference to the rating table of the turbidimeter. The readings were made in a darkened place and usually after dark. It was customary to average the results obtained on three or more precipitations. Direct readings were made for amounts between 30 and 400 parts per million, and less than 30 parts were estimated as trace, 5, 10, or 20 parts by the turbid appearance of the mixture. Appropriate dilutions were made for amounts exceeding 400 parts.

TOTAL HARDNESS.

Total hardness is determined in the field tests by adding to a measured amount of the water tablets containing a known amount of sodium oleate until the liquid after vigorous shaking forms a foam that does not break in five minutes while the bottle rests in a horizontal position. This substitution of tablets for the soap solution commonly employed in the laboratory is entirely satisfactory from the standpoint of accuracy, and it also obviates carrying a bulky bottle of soap, but so many tests had to be made and the time consumed in grinding the oleate tablets is so considerable that it was more economical to use a short burette and an alcoholic solution of Castile soap each cubic centimeter of which was equivalent to about 1 milligram of $CaCO_3$. Fifty cubic centimeters of water was titrated, allowance being made in computing the hardness for the soap consumed by 50 cubic centimeters of distilled water. So much dependence is placed on the estimate of total hardness in interpreting the results of the field assays that dilutions with distilled water were frequently made in order that interference by the insoluble soaps of the alkaline earths might be avoided.

PROBABLE ACCURACY.

Thirty-two waters that were analyzed by Mr. F. M. Eaton were also assayed in the field, and the results of analyses and assays are compared in Table 7. The bicarbonate and carbonate in both sets have been recomputed to CO_3 because changes in the condition of

the carbonates during the time between assay and analysis make comparison difficult unless this is done. The computation does not affect the accuracy of the results in any way.

TABLE 7.—*Comparison of field and laboratory results of the examination of 32 waters from San Joaquin Valley.*

[Parts per million.]

No.	Carbonate radicle (CO_3).		Sulphate radicle (SO_4).		Chlorine (Cl).		Total hardness as $CaCO_3$.	
	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.[a]
1	24	25	5	0	10	5.4	41	48
2	34	35	Tr.	2.9	5	6.0	51	47
3	37	39	Tr.	0	10	8.0	59	51
4	36	40	10	8.2	15	14	40	42
5	40	44	Tr.	0	30	25	63	76
6	60	66	Tr.	0	10	5.9	84	80
7	50	38	Tr.	0	25	22	87	40
8	67	73	Tr.	0	15	15	151	144
9	60	65	Tr.	0	20	15	111	113
10	50	57	5	7.0	35	35	51	56
11	75	78	Tr.	3.7	15	10	122	114
12	63	65	Tr.	4.1	25	22	3	19
13	73	81	5	1.6	20	19	94	94
14	44	44	20	66	50	48	96	122
15	99	103	Tr.	6.6	5	6.0	24	38
16	64	65	Tr.	0	55	51	68	67
17	80	92	Tr.	0	35	35	44	59
18	87	83	55	45	55	58	250	160
19	46	45	Tr.	0	110	112	28	28
20	147	159	Tr.	0	20	22	11	26
21	115	101	10	0	65	64	68	71
22	185	198	5	4.9	280	279	28	31
23	87	95	395	541	115	128	80	91
24	75	70	52	45	470	433	505	450
25	72	76	800	713	85	86	810	754
26	82	96	764	600	165	153	953	698
27	88	94	828	711	125	122	854	1,027
28	77	68	471	441	445	481	162	120
29	828	962	Tr.	0	490	492	535	655
30	101	108	1,640	718	210	196	1,220	1,240
31	860	841	5	0	1,380	1,418	59	30
32	38	42	5	0	4,110	4,310	1,838	2,773

[a] Computed from values for calcium and magnesium.

In Eaton's tests 100 cubic centimeters of water was evaporated to dryness, and the residue was dried at 180° C. for estimation of dissolved solids. Iron was estimated colorimetrically and calcium and magnesium gravimetrically in that residue. Carbonate, bicarbonate, and chloride were determined by titration in ordinary manner, and sulphate by precipitating and weighing as barium sulphate the sulphate in 100 cubic centimeters of the sample. The content of the alkalies, expressed as parts per million of sodium, was computed from these estimates by means of the following formula. The symbols represent the amounts in parts per million of the radicles, and their respective coefficients are obtained by dividing their valences by their molecular weights.

$$Na = 23(0.0333CO_3 + 0.0164HCO_3 + 0.0208SO_4 + 0.0282Cl - 0.0499Ca - 0.0821Mg).$$

The two sets of carbonate determinations in Table 7 show numerical differences ranging from 0 to 134; only one set, however, has a relative difference exceeding 14 per cent and the average difference of the other 31 sets is 7 per cent. This is not unreasonable in view of the better light and other facilities in the laboratory, and it should be remembered also that all the figures are results of single determinations with unusually small quantities of water. The usual error in the determinations of low chlorines by field assay is 5 parts or less because most of the estimates were performed with 50 cubic centimeters of water. The average difference of the 11 sets of figures exceeding 100 parts per million is less than 6 per cent. Evidently field estimates of chlorine should be expressed not more exactly than to the nearest 5 parts per million and not more than three significant figures should be given.

As total hardness was not determined in the laboratory, a comparative figure has been calculated from the amounts of calcium and magnesium by means of the following formula, in which H, Ca, and Mg represent respectively total hardness as $CaCO_3$, calcium, and magnesium in parts per million:

$$H=2.5\ Ca+4.1\ Mg.$$

Though this formula expresses the theoretical relation between the amounts of calcium and magnesium and the hardness found by titration with soap and conventionally expressed as $CaCO_3$ actual determinations do not agree exactly, because the soap titration is subject to obscure errors and because the form of computation magnifies errors in the estimates of the bases. Yet review of the columns showing total hardness indicates that the results obtained by titration convey an approximate idea of the amount of the alkaline-earth bases, though the proportionate differences of single determinations are fairly high. Possibly more nearly accurate estimates could have been made by using a weaker soap solution and greater dilutions.

The estimates of appreciable amounts of sulphate are too few to permit computation of a probable error, but it is apparent that the procedure gives estimates near enough to the correct values for use in approximate classification. The field estimate of sulphate in set No. 14 is obviously incorrect, and other computations indicate that the laboratory report of sulphate in set No. 30 is one-half what it should be.[1]

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[1] See also Dole, R. B., The field assay of water: Eng. News, vol. 64, p. 145, 1910; Rapid examination of water in geologic surveys of water resources: Econ. Geology, vol. 6, June, 1911.

INTERPRETATION OF RESULTS.

For the purpose of ascertaining how much dependence may be placed on field assays—that is, how interpretations of them compare with those of examinations more carefully made and also how far such interpretations agree with practical experience in using the waters in question—certain values have been computed from the data of the 32 analyses and assays of the same waters in Table 7, and notes have been made of the known uses of the waters. The values in the columns headed "Field," in Table 8, are calculated from the assays and in those headed "Laboratory," from Eaton's more complete analyses, except the figure for total solids in the laboratory results, which was obtained directly by weighing the residue dried at 180° C. The computations and classifications are made by means of formulas and ratings explained on pages 50–82.

Table 8.—*Comparison of ratings by field assays and by laboratory analyses.*

[Parts per million except as otherwise designated.]

No.	Computed values. Total solids.		Scale-forming ingredients (s).		Foaming ingredients (f).		Probability of corrosion[b] (c).		Alkali coefficient (inches).		Classification. Mineral content.		Chemical character.		Quality for irrigation.		Quality for boiler use.		Remarks.
	Field.	Laboratory.[a]	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	
1	120	138	90	90	30	3	N. C.	?	140	400	Low	Low	Ca-CO_3	Ca-CO_3	Good.	Good.	Good	Good	Irrigates garden.
2	120	178	100	90	15	30	N. C.	N. C.	200	85	do	Moderate.	do	do	do	do	Fair	do	Used for bottle washing
3	130	150	110	95	50	30	N. C.	N. C.	45	70	do	Low	do	do	do	do	do	Fair	Used in boilers and for beer making.
4	150	140	90	90	70	70	N. C.	N. C.	40	40	do	do	Na-CO_3	Na-CO_3	do	do	Good	Good	Domestic use and for stock.
5	170	200	110	125	50	40	N. C.	N. C.	70	80	Moderate.	Moderate.	Ca-CO_3	Ca-CO_3	do	do	Fair	Fair	Irrigates alfalfa.
6	170	180	130	115	40	50	N. C.	N. C.	55	40	do	do	do	do	do	do	do	do	Used in boilers and for wine making.
7	180	168	140	85	40	70	N. C.	N. C.	80	37	do	do	do	Na-CO_3	do	do	do	Good	Domestic use and for stock.
8	190	225	200	180	0	0	?	?	140	140	do	do	do	Ca-CO_3	do	do	do	Fair	Irrigates fruit trees.
9	190	210	160	150	30	20	N. C.	N. C.	100	140	do	do	do	do	do	do	do	do	Irrigates grapes and alfalfa.
10	200	218	100	110	120	120	N. C.	N. C.	50	22	do	do	Na-CO_3	Na-CO_3	do	do	do	do	Domestic use and for stock.
11	210	210	170	150	30	45	N. C.	N. C.	140	60	do	do	Ca-CO_3	Ca-CO_3	do	do	do	do	Not used.
12	200	202	55	65	190	150	N. C.	N. C.	11	14	do	do	Na-CO_3	Na-CO_3	Fair	Fair	do	Good	Irrigates alfalfa.
13	220	200	140	135	80	80	N. C.	N. C.	30	27	do	do	Ca-CO_3	Ca-CO_3	Good.	Good.	do	Fair	Irrigates garden.
14	240	364	150	180	90	110	?	?	40	40	do	do	do	Ca-SO_4	do	do	do	do	Locomotive supply.
15	230	266	70	90	200	190	N. C.	N. C.	9	10	do	do	Na-CO_3	Na-CO_3	Fair	Fair	do	do	Domestic use and for stock.
16	250	232	120	120	160	140	N. C.	N. C.	16	19	do	do	do	do	do	Good.	do	do	Do.
17	250	220	90	110	190	180	N. C.	N. C.	11	12	do	do	do	do	do	Fair	do	do	To be used on alfalfa.
18	370	344	300	180	40	40	?	?	35	35	do	do	Ca-CO_3	Ca-CO_3	Good.	Good.	Poor	do	Domestic use and for stock
19	310	312	80	80	280	260	N. C.	N. C.	10	11	do	do	Na-Cl	Na-Cl	Fair	Fair	Bad	Bad	Irrigates wheat and alfalfa.
20	340	386	60	75	360	340	N. C.	N. C.	5	5.6	do	do	Na-CO_3	Na-CO_3	Poor.	Poor.	do	do	Supplies watering trough.
21	370	350	120	90	310	230	N. C.	N. C.	7	10	do	do	do	do	Fair	Fair	do	Fair	City supply.
22	810	872	60	60	920	860	N. C.	N. C.	3	2.9	High	High	Na-Cl	Na-Cl	Poor.	Poor.	Very bad	Very bad	Said to kill vegetation.
23	950	1,268	110	125	860	1,000	N. C.	N. C.	6	9	do	do	Na-SO_4	Na-SO_4	Fair	Fair	do	do	Irrigates lawn and shade trees; softened for boiler use.

[a] Determined values.

[b] N. C.=Noncorrosive; C.=corrosive; ?=corrosive tendency unknown.

TABLE 8.—*Comparison of ratings by field assays and by laboratory analyses*—Continued.

No.	Computed values.										Classification.									Remarks.
	Total solids.		Scale-forming ingredients (s).		Foaming ingredients (f).		Probability of corrosion (c).		Alkali coefficient (inches).		Mineral content.		Chemical character.		Quality for irrigation.		Quality for boiler use.		
	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	Field.	Laboratory.	
24	1,000	1,118	530	400	460	400	?	C.	4	4.7	High..	High..	Ca-Cl....	Ca-Cl....	Poor.	Poor.	Very bad	Very bad	Domestic use.
25	1,500	1,702	840	600	360	290	C.	C.	19	20	...do..	...do..	$Ca\text{-}SO_4$..	$Ca\text{-}SO_4$..	Good.	Good.	...do....	...do....	Irrigates garden.
26	1,600	1,392	980	580	270	380	C.	C.	12	12	...do..	...do..	...do....	...do....	Fair..	Fair..	...do....	Bad.....	Domestic use and for stock.
27	1,600	1,826	880	830	440	50	C.	C.	14	17	...do..	...do..	...do....	...do....	...do.	...do.	...do....	Very bad	Irrigates alfalfa.
28	1,600	1,616	190	150	1,500	1,400	?	?	4	4.2	...do..	...do..	Na-Cl...	Na-Cl...	Poor.	Poor.	...do....	...do....	Domestic use and for stock.
29	2,300	2,452	560	450	2,100	2,000	N. C.	N. C.	1.1	1.1	Very high.	Very high.	$Na\text{-}CO_3$.	$Na\text{-}CO_3$.	Bad..	Bad..	...do....	...do....	Not used.
30	3,000	3,210	1,300	980	1,300	0	C.	C.	6	10	...do..	...do..	$Ca\text{-}SO_4$..	$Ca\text{-}SO_4$..	Fair..	Fair..	...do....	...do....	Said to be injurious in irrigation.
31	3,800	3,930	90	60	4,500	4,200	N. C.	N. C.	.5	.6	...do..	...do..	Na-Cl...	Na-Cl...	Bad..	Bad..	...do....	...do....	Not used.
32	6,800	7,489	1,900	2,590	5,400	4,200	C.	C.	.5	.5	...do..	...do..	..do....	...do....	...do.	...do.	...do....	...do....	Do.

Nearly all the numerical differences in the computed amounts become insignificant when the values are interpreted according to the ratings that are discussed on pages 50-82. For example, the difference between the alkali coefficients of the first two waters is very great, but as any value exceeding 18 indicates a water good for irrigation the discrepancy of the computed coefficients is negligible. The coefficients agree more closely as the concentration of the mineral matter increases so that the two sets of figures are nearly alike for the poorer waters. The distinction in set No. 16, which is the only pair in which a difference of interpretation occurs, is due only to strict application of the rating according to which the coefficient, 18, is the dividing line between "good" and "fair" waters. The notes under "Remarks" show that the classification coincides with experience in applying the waters to crops. Five of those rated as good for irrigation and four of those rated as fair have been used for several years on various cultures without apparent trouble. No. 17, rated as fair, is to be used for irrigating alfalfa. No. 25, a calcium sulphate water high in mineral matter but rated as good for irrigation, has been used on a variety of small cultures for one year without apparent harm, while it is said that No. 30, which is in the same neighborhood but is distinctly more highly mineralized, can be used to irrigate nothing but alfalfa, probably an old growth. No. 22, classed as poor, is on an abandoned farm, but it is reported to have been unsuccessfully used for irrigating grain. None of the other supplies rated as poor or bad is applied to crops. Many of the differences in the computed values of scale-forming and foaming constituents become insignificant in classification, yet five sets show distinction in class; the differences in sets Nos. 2, 12, and 21 are caused by strict application of the rating tables to estimates that are rather close to the lines of division, and they illustrate well the difficulty that is always experienced in attempting to translate the figures of an analysis into descriptive adjectives. For example, the small difference of 10 parts per million in the estimates of scale-forming ingredients in set No. 2 changes the classification. No importance can be attached to the difference between 3 and 30, the estimated amounts of foaming constituents in the first water, because both numbers are far below the point where the foaming tendency must be considered; similarly, the numerically large discrepancy in corresponding values for No. 23 has no practical significance as either estimate indicates that the water would foam badly. An incorrect determination of total hardness is responsible for the difference in the computed values of the foaming constituents in No. 27, and an unexplained but obvious difference in the estimates of sulphate accounts for a like difference in No. 30, but neither pre-

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vents proper classification of the waters in respect to their value for boiler use. The computed amounts of total solids agree well with those determined by weighing, except in No. 14, where the difference in classification is traceable to the difference in sulphate already mentioned.

Altogether this comparison demonstrates one of the many practical purposes for which rapid methods of water-testing are economical—for selecting waters that are extremely good or extremely bad, thus greatly reducing the number of samples that must be sent to the laboratory for detailed and much more expensive analysis. Field assays afford estimates of much practical value when they are interpreted by the broad standards proper for water ratings, though they can never rival complete analyses in accuracy or in general availability. The comparative inexpensiveness of the assay opens a large and legitimate field of activity, for by means of it agriculturists, geologists, chemists, and others engaged in water investigations can obtain information regarding mineral constituents general in character but essentially practical. The rapidity with which the assays can be made makes it possible to perform the large number of examinations necessary in studying the quality of water over any extensive area.

PROCEDURES OF THE SOUTHERN PACIFIC CO.

A large proportion of the miscellaneous analyses were performed in the laboratory of the Southern Pacific Co. at Sacramento. By the procedures of that laboratory the residue from 1,000 cubic centimeters of the sample, after having been dried at 160° C. to a constant weight, is separated into a soluble and an insoluble portion by treatment with 150 cubic centimeters of hot distilled water. Silica, calcium, and magnesium are estimated in each portion, and the alkalies in the soluble portion are calculated by difference. Chloride, sulphate, nitrate, and carbonate are estimated in separate portions of water by common methods. The results of these tests, stated by the analyst in the form of compounds, have been computed to ionic form in parts per million in order that they may be comparable with other tests.

STANDARDS FOR CLASSIFICATION.

MINERAL CONSTITUENTS OF WATER.

All natural waters contain dissolved or suspended materials with which they have come into contact. They take up such materials in amounts determined principally by the chemical composition and physical structure of the substances, by the temperature, pressure, and duration of their contact, and by the condition of substances that they have previously incorporated. For purposes of examination

the substances that may be present in natural waters are classified as suspended matter, such as particles of clay or leaves; dissolved matter, either of mineral or organic origin; microscopic animals or plants; and bacteria. The presence of very small animals and plants likely to affect the quality of water is determined by microscopic examination, and the chance of contracting disease by drinking the water is ascertained by bacteriologic processes. The amount and nature of the mineral ingredients are most commonly determined by estimating the total suspended matter, total dissolved matter, total hardness, total alkalinity, silica, iron, aluminum, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulphate, nitrate, chloride, free carbonic acid, and free hydrogen sulphide, these being the materials most commonly present and most likely to affect the value of the waters.

WATER FOR IRRIGATION.

SOURCE OF ALKALI.

Many mineral substances are injurious to vegetation, but the only ones that are usually abundant enough to demand attention are compounds of sodium, or, as they are commonly termed, "the alkalies." Though potassium in nominal quantity is a plant food, it is usually not separated from sodium in commercial analyses of water, the two bases being estimated together and reported as sodium; but as the proportion of potassium in highly mineralized waters is commonly low compared with that of sodium this disregard of potassium does not lead to any considerable error in judging the value for irrigation. During the natural decomposition or rotting of rocks and soils salts of the alkalies, easily soluble in water, are formed. These compounds are leached from the soil and washed away in regions where plenty of rain falls, and consequently they do not become concentrated enough to damage crops; but wherever the rainfall is insufficient to effect this removal such materials continually increase, and the proportion of them may become so great that plants are stunted or killed and the ground becomes unproductive.

Accumulations of alkali can also be caused in another way. All waters that penetrate the ground either naturally or as a result of irrigation contain these salts in solution, and evaporation of the water, leaving the salts, adds to the supply that has been formed by decomposition of rock. Such concentration of soluble salts has been taking place for a long time in the basin of Tulare Lake, the waters of which have been removed many times by evaporation, leaving a residue of salts to mix with those already in the ground. The effect of waters applied during irrigation is all that is properly within the scope of this section, but certain general features in connection with

the occurrence of alkali should be considered, because the soluble salts normally formed in the soil and those introduced by the water are alike in their nature and their effect.

OCCURRENCE OF ALKALI.

The soluble salts are not evenly distributed over an area or through a given depth, but are ordinarily concentrated in patches near the surface. Such patches may be found in slight depressions into which mineralized water has seeped or drained and from which it has later evaporated. The underground water drawn to the surface by capillarity also brings alkali, which becomes concentrated in the upper layers of the soil. Where the salts are largely sulphates or chlorides the plots are covered with deposits of so-called "white alkali"—that is, crystals of alkaline chlorides and sulphates, mostly common salt and Glauber's salt; but when much carbonate is present the plots are blackened by solution of humus and are termed spots of "black alkali." It can readily be understood from the manner in which the salts are formed and from the possibility of their introduction by seepage or irrigation that the alkali content of a soil can progressively increase until it reaches a strength that will destroy plants previously unaffected. Conversely, a soil that is normally too high in alkali can be rendered productive by washing part of the soluble salts out of it.

If the alkali content of a soil is excessive the growth of cultures is retarded or entirely prevented. A still greater amount of salts kills the most resistant plants, and the area becomes devoid of vegetation. The chief cause of the poisonous action is commonly considered to be abstraction of water from the plant roots by change of the osmotic pressure, but bad effects are also probably more or less due to corrosion of the plant roots, germicidal action on the soil bacteria, and interference with the food supply through solution of humus.

PERMISSIBLE LIMITS OF ALKALI.

The cause and the manner of the harmful action are, however, not so important at present as the amount of these toxic compounds that can be tolerated by crops, for the limit of resistance in soils fixes in turn the maximum content of waters that can safely be used for irrigation, and it indicates the precautions that must be taken in applying the water. Yet it becomes evident from brief consideration of the problem that limits of tolerance must be very broadly interpreted and that absolute classification of waters in respect to their irrigation value is impracticable.

Many investigators have studied the effect on plant growth of mineral substances in water solutions, and the excellent work of Kearney

and Cameron [1] is typical of these. Experimenting with seedlings of white lupine and alfalfa in different strengths of pure solutions, they found that the readily soluble salts common in soils are toxic in the following order: Magnesium sulphate, magnesium chloride, sodium carbonate, sodium sulphate, sodium chloride, sodium bicarbonate, and calcium chloride, the first being 200 times as harmful as the last. But when similar tests were made in the presence of an excess of calcium sulphate and calcium carbonate both the order of toxicity and the maximum concentrations in which the seedlings would grow were entirely changed. The order and the limits for lupine under these conditions are sodium carbonate, 1,560 parts per million; sodium bicarbonate, 4,170 parts; magnesium chloride, 9,600; sodium chloride, 11,600; calcium chloride about 16,000; sodium sulphate, 21,600; and magnesium sulphate, 22,400. Magnesium sulphate, which is most toxic in pure solution, is least harmful in the presence of large amounts of calcium carbonate and sulphate. The chlorides of magnesium, sodium, and calcium follow each other in relative toxicity. The sulphate was found to be the least harmful of the sodium salts, sodium chloride being twice and the carbonate fourteen times as poisonous. These alterations are extremely significant, for none of the salts occurs in large amount in soils except in the presence of large quantities of calcium and more or less of all the other harmful salts. Therefore the death point in a simple solution of one salt is not a safe measure of tolerance, for the power of resistance under natural conditions depends on complex reactions between all the components of the soil solution.

Other investigators have shown not only that different cultures have different degrees of resistance but also that the order of toxicity of the various salts is changed. Some species of rather weak tolerance have also been bred to withstand high concentrations, and it is a matter of ordinary observation in regions of alkali that certain crops die on land where others flourish. The vertical position of the soluble salts also is important. Where, as under ordinary conditions, they are concentrated near the surface they can do the greatest amount of damage because they are in contact with the delicate roots. But they may be washed downward out of the danger zone by proper application of water. All these considerations make it evident that the nature of the crops, the manner of cultivation and irrigation, the

[1] Kearney, T. H., and Cameron, F. K., Some mutual relations between alkali soils and vegetation: U. S. Dept. Agr. Rept. 71, 1902.

Cameron, F. K., and Breazeale, J. F., The toxic action of acids and salts on seedlings: Jour. Phys. Chemistry, vol. 8, p. 1, 1904.

Jensen, G. H., Toxic limits and stimulation effects of some salts and poisons on wheat: Bot. Gazette, vol. 43, p. 11, 1907.

Kahlenberg, L., and True, R. H., The toxic action of dissolved salts and their electrolytic dissociation, Bot. Gazette, vol. 22, p. 81, 1896.

Heald, F. D., The toxic effect of dilute solutions of acids and salts upon plants: Bot. Gazette, vol. 22, p. 125, 1896.

other mineral components of the soil, and many other factors affect tolerance to alkali; when the effects of reactions between the mineral constituents of the soil and of the applied water are added to these modifying features it must be admitted that all general conclusions regarding the potential value of a water supply for irrigation are subject to much modification in particular cases.

Possibly the best basis for conclusions on the value of water for irrigation is the work of Loughridge,[1] who has endeavored to determine the greatest amounts of alkali in the upper 4 feet of ground in the presence of which cultures grow and come to maturity. In pursuance of this plan observations were made of the condition of fruit trees, shrubs, cereals, and other cultivated plants growing or dying in soils, which were then partly analyzed. Loughridge's results are of great practical interest because they are linked with observations on cultures growing under natural conditions on a large scale, and they are here particularly valuable because they represent experiments mostly in the territory covered by this report. Interpretation of the figures is complicated, however, as Loughridge points out, by uncertainty as to whether the observed poor growth was always due to presence of alkali and not to other harmful conditions. As not one alone but all the salts are present in natural soils and as they owe their toxic action to the extent to which they are dissociated, the impossiblity of determining the exact amounts of the different salts in solution or the share of each acid and each basic radicle in the toxic action is fully apparent. Notwithstanding these doubtful points much can be learned from the studies regarding the relative tolerance of cultures.

The amount of alkali that could be tolerated was found to depend largely on the distribution of the salts in the vertical soil column, the injury usually being greatest in the upper foot, where the feeding roots and the greatest amount of alkali occurred together. The range of tolerance for different cultures is very great. Lemon trees, considered very sensitive, were unaffected in the presence of 5,760 pounds of alkali per acre 4-feet, while grapevines withstood nearly eight times as much, or 45,760 pounds. Sorghum flourished in soil containing 81,360 pounds per acre 4-feet, but rye withstood only 12,480 pounds of alkali. The fact that some plants are more readily affected when they are young is well illustrated by alfalfa, which tolerates more than eight times as much alkali when old as when young. Experiments in vineyards showed that different varieties are affected to different degree by alkali and as a corollary that alkali changes the composition of grapes.

[1] Loughridge, R. H., Tolerance of alkali by various cultures: California Univ. Agr. Exper. Sta. Bull. 133, 1901. Quoted by Hilgard, E. W., Soils, p. 467, Macmillan Co., New York, 1906. See also California Univ. Agr. Exper. Sta. Bulls. 128, 140, and 169.

RELATIVE HARMFULNESS OF THE COMMON ALKALIES.

Though various cultures are affected in different degree by sodium in the three common forms of carbonate, chloride, and sulphate, there is some general agreement. Sodium as the carbonate is commonly the most harmful, as the chloride somewhat less so, and as the sulphate least harmful. Hilgard[1] gives the maxima for cereals grown on a certain sandy loam as about 0.1 per cent of sodium carbonate, 0.25 per cent of sodium chloride, and 0.48 per cent of sodium sulphate, corresponding to a toxicity ratio expressed in terms of sodium of 1:1.6:3.6. The relative harmfulness of sodium in the sulphate, chloride, and carbonate, respectively, can be expressed according to Loughridge's results for ten standard crops of San Joaquin Valley by the ratio 1:5:6.6; that is, sodium as the carbonate is 6.6 times as harmful, and sodium as the chloride 5 times as harmful as sodium as the sulphate. A similar ratio for the 15 most sensitive crops is 1:5.3:6.4. If, therefore, sodium as the sulphate is given a toxicity of 1 a reasonably approximate estimate of the relative toxicity of sodium as the sulphate, chloride, and carbonate, respectively, would be expressed by the ratio 1:5:6. Stabler has used in his formulas, quoted later, the ratio 1:5:10 in order to allow for the undesirable puddling of the soil by the carbonate.

RELATION BETWEEN APPLIED WATER AND SOILS.

When water used in irrigating evaporates from the surface of the soil it leaves in the ground its content of salts. If all the applied water were to escape by evaporation, constant use of any supply, no matter how pure it might be, would eventually result in an accumulation of alkali that would render the soil unproductive. If, on the other hand, all of a water not too high in mineral content were to seep downward into the deep-lying strata it would leach out the soluble salts of a highly charged area, which would thus be made productive. Such extreme conditions, however, are not natural. Though evaporation greatly exceeds rainfall in arid regions, and the accumulation of alkali is thus facilitated, part of the water seeping away carries with it a load of salts in solution. Various amounts of mineral matter are also taken up by crops and are removed during harvesting; then, too, the sodium in the soil and in the applied water can be prevented by proper methods of irrigation and drainage from accumulating where it will damage the delicate feeding roots of cultures. Consequently, waters of a relatively low mineral content may be applied year after year without inflicting damage, but those exceeding a certain limit of mineral content are useless for irrigation; waters of an intermediate class, normally capable of increasing the

[1] Hilgard, E. W., Soils, p. 464, Macmillan Co., New York, 1906.

alkalies in the soil, may be harmless under judicious usage. This outline of the general relations between the saline content of soils and of waters used on them indicates other allowances that should be made in estimating to what extent the mineral matter in applied waters affects their value for irrigation.

NUMERICAL STANDARDS.

Twelve hundred parts per million of mineral matter is the limit of concentration given by Hilgard [1] for irrigation water in all cases under the ordinary practice in California. This limit is greatly modified by the character of the dissolved salts, and the results of extensive irrigation elsewhere indicate that very much stronger waters can be used on some soils if they are properly applied. Basing his computations on Loughridge's determinations of tolerance,[2] Stabler [3] has developed formulas for rating waters in respect to their value for irrigation. His comparison is made by means of an "alkali coefficient" (k), which is defined as the depth in inches of water which would yield on evaporation sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops. The sodium equivalents of the three common salts of sodium, the sulphate, chloride, and carbonate, are assigned relative toxicities of 1, 5, and 10, respectively, and the maximum tolerance of sensitive cultures is taken as 1,500 pounds of sodium in the form of sulphate per acre 4-feet. The correctness of the latter assumption by itself might be questioned in view of the fact that Loughridge's figures for cultures at the lower end of his lists are particularly liable to upward revision after further investigation. Yet this should not lead to appreciable error as the chief value of the formulas rests in the ratio of toxicities and the interpretation of the computed value of k.

If $Na - 0.65\ Cl$ is zero or negative, $k = \frac{2{,}040}{Cl}$.

If $Na - 0.65\ Cl$ is positive but not greater than $0.48\ SO_4$, $k = \frac{6{,}620}{Na + 2.6\ Cl}$.

If $Na - 0.65\ Cl - 0.48\ SO_4$ is positive, $k = \frac{662}{Na - 0.33\ Cl - 0.43\ SO_4}$.

The alkali coefficient, k, is in inches as already explained; the symbols SO_4, Cl, and Na represent, respectively, the amounts in parts per million in the water of sulphate, chlorine, and alkalies, the latter being commonly grouped under the name of sodium. Consideration of bicarbonate is precluded because estimates of it apparently were not made in the work on which the formulas are based. The three formulas represent the different relations between

[1] Op. cit., p. 248.

[2] Loughridge, R. H., Tolerance of alkali by various cultures: California Univ. Exper. Sta. Bull. 133, 1901.

[3] Stabler, Herman, Some stream waters of the western United States, with chapters on sediment carried by the Rio Grande and the industrial application of water analyses: U. S. Geol. Survey Water-Supply Paper 274, p. 177, 1911. See also Eng. News, vol. 64, p. 57, 1910.

the alkali and the acid radicles. Under the first condition, with enough, or more than enough, chlorine to satisfy sodium, it is assumed that chlorides other than that of sodium are as harmful as that compound. Cameron[1] found that magnesium chloride, sodium chloride, and calcium chloride had relative toxicities of 1.2: 1.0: 0.6, respectively, in the presence of an excess of calcium sulphate or of calcium sulphate and calcium carbonate. Under the second condition, where the chloride and sulphate radicles together are sufficient to satisfy sodium, and under the third, where both chlorine and sulphate are insufficient to satisfy sodium, magnesium is assumed to have no deleterious effect. This base loses the greater part of its toxic power when much calcium is present and therefore this assumption seems justifiable as not only is calcium usually high in all soils but also it commonly exceeds the proportion of magnesium in natural waters. Though the formulas are based on the relative predominance of the radicles, they should not be interpreted as signifying that the acids and bases are combined but as presenting the maximum possibilities of the deposition of harmful alkali salts in the soil layer. Waters to which the first two formulas are applicable are likely to leave white alkali on evaporation, and those in the third class probably yield black alkali.

The approximate amount of alkali in a water can be computed from the results of a field assay by the following formula:

$$Na = 0.83\ CO_3 + 0.41\ HCO_3 + 0.71\ Cl + 0.52\ SO_4 - 0.5\ H.$$

The symbols represent the amounts in parts per million of alkali (sodium and potassium) and the carbonate, bicarbonate, chlorine, sulphate, and total hardness found by assay. The equation expresses the theoretical relation that the sum of the reacting values of the acid radicles minus the reacting values of calcium and magnesium, which together are one-fiftieth of total hardness, equals the reacting value of the alkalies; the factor 25 instead of 23, the atomic weight of sodium, is used for safety. Because of the approximate nature of the figures of field assays values of k computed from them should be reported with not more than two significant figures and to the nearest 10 when they exceed 30.

The following ratings for interpreting values of the alkali coefficient are proposed by Stabler:

TABLE 9.—*Classification of water for irrigation.*

Value of k.	Classification.
Greater than 18	Good.
6 to 18	Fair.
1.2 to 5.9	Poor.
Less than 1.2	Bad.

[1] Cameron, F. K., and Breazeale, J. F., The toxic action of acids and salts on seedlings: Jour. Phys. Chemistry, vol. 8, p. 1, 1904.

The value of k, showing the number of inches of water that would yield on evaporation sufficient alkali to inhibit the growth of very sensitive plants, indicates the relative degree of care that is essential in applying a water to irrigated tracts. As defined by Stabler, "good" waters are those that can be used for many years without special care to prevent alkali accumulation. Waters classed as "fair" require special care to prevent gradual concentration of alkali except in loose soils with free natural drainage. In using waters classed as "poor" care in selection of soils has been imperative and artificial drainage has frequently been necessary. The "bad" waters contain so much harmful matter in solution that they are practically valueless for irrigation. These ratings are based on general practice in the arid and semiarid regions of the United States, and so far as they can be checked by comparison with actual experience in the use of waters in San Joaquin Valley they answer all practical purposes.

This rating, like any other that might be devised, should be liberally interpreted. It is well to repeat emphatically that it signifies only a comparison of the waters themselves on the basis of their mineral content. It has no reference whatever to the possibility of raising good crops on land to which the waters may be applied, because it does not take into account the alkali content and the texture of the soil, drainage conditions, the method of irrigation, the duty of the water, or the other factors on which agricultural success depends.

REMEDIES FOR ALKALI TROUBLES.

WASHING DOWN THE ALKALI.

The relation between applied water and soils makes it apparent that the farmer can control the alkali content of his ground to great extent by the manner in which he applies water and the care he takes to prevent accumulation of soluble salts near the surface. When a deep, readily pervious soil is covered with water to a proper depth by flooding, which is widely practiced in San Joaquin Valley, the water rapidly soaks into the soil, dissolving the alkali salts concentrated near the surface and carrying them downward beyond the zone of influence on the delicate feeding rootlets. But if the ground is not then protected against surface evaporation the water is drawn upward and alkali again impregnates the top layers. This action can be prevented in some measure by thorough cultivation as soon as possible after irrigation, and the shade afforded by trees and good stands of grass or grain also minimizes it. This shading effect partly explains why well-established growths of some cultures can thrive in soil containing an amount of alkali injurious to younger crops. A good stand of alfalfa, for instance, inhibits surface evaporation and consequent rise of alkali to the feeding roots, though the ground

deeper down may contain enough alkali to kill the plants; whereas newly started alfalfa can not prevent evaporation, and the alkali, dissolved by the water and rising with it by capillarity, becomes concentrated where it can do the greatest damage. A shallow soil underlain by hardpan is not benefited by flooding alone, as the leaching is stopped by the impervious layer.

It is a prevalent idea that alkali can be washed from a piece of land by flooding it with large quantities of water and then allowing the surplus to run off. The improvement is, however, not due so much to removal of the comparatively small quantities of material carried away in the off-flow as to depression of the alkali by the downward percolation just described. The results of some experiments by Headden[1] illustrate this well. Two waters, the composition of which is given in columns A and B of Table 10, were used during two successive days to flood a tract of alkali land about 600 feet long. Four samples of the off-flow were taken, two at the beginning of the off-flow and two just before the on-flow was stopped, and the average of the analyses of these four samples is given in column C. Though one of them, taken at the very commencement of the off-flow, carried 1,238 parts per million of dissolved solids, this high content lasted only a few minutes, and comparison of the average with the results in columns A and B shows how little the total mineral content of the water that remained above ground and finally flowed off after crossing the entire area was increased by solution of the alkali in the soil.

TABLE 10.—*Effect of flooding on alkali as shown by composition of water.*

[Parts per million.]

Constituents.	A	B	C	D	E
Total solids	328	706	760	1,415	3,278
Organic and volatile matter	27	37	44	92	145
Silica (SiO_2)	10	14	12	23	20
Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$)	1.0	3.4	.8	1.6	.7
Calcium (Ca)	43	90	93	139	314
Magnesium (Mg)	10	24	30	66	170
Manganese (Mn)	.6	.8	.2	.7	1.0
Sodium (Na)	42	96	102	195	436
Potassium (K)	3.6	3.8	5.6	1.9	6.4
Carbonate radicle (CO_3)	64	106	112	120	149
Sulphate radicle (SO_4)	113	305	335	713	1,885
Chlorine (Cl)	10	24	24	60	147

A. Water used in irrigating on Sept. 1.
B. Water used in irrigating on Sept. 2.
C. Average composition of off-flow Sept. 2.
D. Average composition of water from 4 shallow wells Aug. 31.
E. Average composition of water from 4 shallow wells Sept. 2.

Four shallow wells in the plot, protected against entrance of water over the top, were sampled before (column D) and after irrigation

[1] Headden, W. P., Colorado irrigation waters and their changes: Colorado Agr. Coll. Exper. Sta. Bull. 82, 1903.

(column E). The composition of the ground water portrayed by these averages is typical in showing the downward passage of the alkali salts in the soil. The average amount of mineral matter in the off-flow is only slightly greater than that in the applied water that was used in greater quantity, but the water in the wells increased in dissolved solids from 1,415 parts to 3,278 parts per million, calcium, magnesium, sodium, sulphate, and chloride having been more than doubled. Headden estimates that the ground water gained about 5,000 pounds of mineral matter per acre-foot of water by this irrigation.

The effect of natural precipitation in washing down the soluble salts can be illustrated by analyses of water from the same wells after a long period of heavy rainfall. Just before the rain stopped the water of one well contained 10,360 parts per million of total solids, an amount several times the normal; only eight days later solids had fallen to 6,450 parts; and to 2,030 parts after a month. This decided increase of mineral content after rainfall and the subsequent decrease coincident with the loss of water by evaporation and drainage can be explained by change in position of the soluble salts in the soil column.

Irrigation by shallow furrows from which the water soaks into the ground is practiced extensively in orchards and truck gardens throughout San Joaquin Valley. This causes downward transmission of alkali in pervious soils like flooding, with the added advantage that the decreased evaporation lessens the tendency toward surface concentration of alkali. Deep, narrow furrows would undoubtedly still further reduce the proportion of water lost by evaporation and would prevent the rise of alkali by affording deeper circulation of the water supply.

DRAINAGE.

Such downward washing of soluble substances affords no permanent relief, for the alkali, not being removed, may be drawn again to the surface, or may rise as a result of wasteful irrigation, a trouble common in water-logged soils. Downward washing can be safely relied on only when the soils are pervious and have good natural drainage. Application of heavily mineralized water even under such conditions year after year may increase the amount of the harmful ingredients and render them more difficult to handle. The recognized permanent remedy is installation of underdrains, through which the dissolved substances may be removed. The installation of drainage is costly, but it has become an essential part of irrigation systems wherever the soils are very bad or the waters are high in harmful ingredients, for it not only facilitates the removal of the deleterious salts originally in the ground, but also affords means for preventing accumulation of alkali when very strong waters are used.

The experimental plots cultivated by the Department of Agriculture in Fresno County where the "rise of the alkali" has spoiled otherwise good ground have been thoroughly reclaimed by underdrainage.[1] Many of the waters of the valley now considered poor for irrigation can probably be utilized on well-drained tracts, for sodium chloride waters far more concentrated than some of the poorer ones in the trough of San Joaquin Valley are being successfully applied to Algerian lands [2] that are thoroughly drained. The best results with strong saline waters have been obtained by irrigating copiously at frequent intervals. In conjunction with free drainage such operation prevents concentration of alkali salts in the soil, for any accumulation that may form is quickly dissolved and washed downward.

MISCELLANEOUS REMEDIES.

Though it is possible to remove a large proportion of the alkali crust by scraping the surface of the land that method is too expensive to be generally adopted. Growing and completely cropping plants that secrete relatively large quantities of alkali is tedious but fairly successful. The injurious effect of carbonate alkali can be greatly reduced by spreading the ground with gypsum, by action of which carbonate of lime and alkali sulphates are formed. As carbonate alkalies are much more harmful than chlorides or sulphates treatment of this character lessens the toxic action.

WATER FOR BOILER USE.

FORMATION OF SCALE.

The most common trouble in boilers is formation of scale, or deposition of mineral matter within the boiler shell. When water is heated under pressure and concentrated by evaporation, as in a boiler, certain substances are thrown out of solution and solidify on the flues and crown sheets or within the tubes. These deposits increase fuel consumption because they are poor conductors of heat and increase the cost of boiler repairs and attendance because they have to be removed. If the amount of scale is great or if it is allowed to accumulate the boiler capacity is decreased and disastrous explosions are likely to occur.

The incrustation (scale) consists of the substances that are insoluble in the feed water or become so within the boiler under conditions of ordinary operation. It includes practically all the suspended matter, or mud; the silica, probably precipitated as the oxide (SiO_2); the iron and aluminum, appearing in the scale as oxides or hydrated

[1] Fortier, Samuel, and Cone, V. M., Drainage of irrigated lands in the San Joaquin Valley, California: U. S. Dept. Agr. Exper. Sta. Bull. 217, 1909.

[2] Means, T. H., The use of alkaline waters for irrigation: U. S. Dept. Agr. Bur. Soils Circ. 10, 1903; also U. S. Geol. Survey Water-Supply Paper 93, p. 255, 1904.

oxides; the calcium, precipitated principally as carbonate and sulphate; and the magnesium, found chiefly as oxide but also partly as carbonate. Scale is therefore a mixture, which varies in amount, density, hardness, and composition with the quality of water supply, the steam pressure, the type of boiler, and other conditions of use. Calcium and magnesium are the principal basic substances in the scale, over 90 per cent of which usually is calcium, magnesium, carbonate, and sulphate. If much organic matter is present part of it is precipitated with the mineral scale, as the organic matter is decomposed by heat or by reaction with other substances. If magnesium and sulphate are comparatively low or if suspended matter is comparatively high the scale is soft and bulky and may be in the form of sludge that can be blown or washed from the boiler. On the other hand, a clear water relatively high in magnesium and sulphate may produce a hard, compact scale that is nearly as dense as porcelain, clings to the tubes, and offers great resistance to the transmission of heat. Therefore the value of a water for boiler use depends not only on the quantity but also on the physical structure of the scale produced by it.

CORROSION.

Corrosion or "pitting" is caused chiefly by the solvent action of acids on the iron of the boiler. Free acids capable of dissolving iron occur in some natural waters, especially in the drainage from coal mines, which usually contains free sulphuric acid, and also in some factory wastes draining into streams. Many ground waters contain free hydrogen sulphide, a gas that readily attacks boilers, and some contain dissolved oxygen and free carbon dioxide, which are also corrosive. Organic matter is probably a source of acids, for waters high in organic matter and low in calcium and magnesium are corrosive, though the nature and action of the organic bodies are not well understood. The chief corrosives are acids freed in the boiler by the deposition of hydrates of iron, aluminum, and magnesium, the last-named being the most important as it is the most abundant. The acid radicles that were in equilibrium with these bases may pass into equilibrium with other bases, displacing equivalent quantities of carbonate and bicarbonate; or they may decompose carbonates that have been precipitated as scale; or they may combine with the iron of the boiler, thus causing corrosion; or they may do all three, their action depending on the chemical composition of the water. Even with the most complete analyses this action can be predicted only as a probability. If the acid thus freed exceeds the amount required to decompose the carbonate and bicarbonate radicles it attacks the iron of the boiler and produces pits or tuberculations of the interior surface, leaks, particularly around rivets, and general deterioration.

FOAMING.

Foaming is rising of the water in the boiler and particularly in the steam space normally above the water, and it is intimately connected with priming, which is the passage from the boiler of water mixed with steam. Foaming results when anything prevents the free escape of steam from the water. It is usually ascribed to an excess of dissolved matter that increases the surface tension of the liquid and thereby reduces the readiness with which the steam bubbles break. As sodium and potassium remain dissolved in the boiler water while the greater portion of the other bases is precipitated, the foaming tendency is commonly measured by the degree of concentration of the alkali salts in solution, because this figure in connection with the type of boiler determines to great extent the length of time that a boiler may run without danger of foaming. It is a fact that the worst foaming waters in railroad practice are encountered in the arid and semiarid regions of the Southwest where the quantity of dissolved alkali is greatest. However, it is well known that suspended matter can cause foaming, for certain waters that deposit a moderate amount of scale but do not foam when clear foam badly when they carry a great quantity of mud. Greth [1] states that foaming is due to condition of boiler, design of boiler, size and shape of water space, steam pipe, irregularity in blowing off, introduction of oil into the feed water from the exhaust steam, neglect to change water periodically, irregularity of load, or improper firing and feeding. He concludes that it is not merely the presence of sodium salts in solution that causes foaming, but the presence of other substances which together with the sodium salts and operating conditions bring about foaming. The writer believes that a strong solution of sodium carbonate might not induce excessive foaming in water otherwise pure, but its introduction into a boiler, which under operating conditions invariably contains suspended matter or precipitated sludge, might produce foaming by increasing the suspended matter either by precipitating calcium and magnesium or by loosening previously deposited scale. Under working conditions it is difficult to distinguish the actual cause of the trouble. Experience has shown that the type of boiler, steam pressure, and other operating conditions may greatly accelerate or retard foaming.

REMEDIES FOR BOILER TROUBLES.

The best way of remedying unsatisfactory boiler supplies is to treat them before they enter boilers, but where this is impracticable trouble can be minimized in various ways. Low-pressure large-flue

[1] Greth, J. C. W., Water softening and purification for coal-mine operations (paper read before the West Virginia Coal Mining Institute, Bluefield, W. Va., June 7, 1910).

boilers are used in many stationary plants with hard waters, and it is said that the scale formed in them is softer and more flocculent and can therefore be more readily removed than that formed in high-pressure boilers. Blowing off is about the only practical means of preventing foaming, because this trouble is due principally to concentration of substances in the residual water of the boilers. Accumulated sludge, or soft scale, is removed by blowing, particularly in locomotive practice. In condensing systems much of the trouble due to mineral matter in the feed water is obviated because the quantity of raw water supplied is proportionately small. Yet the problem is not completely solved in such systems, because the incrusting or corrosive action is transferred from the boiler to the condenser, which requires more or less cleaning and repairing in proportion to the undesirable qualities of the water supply.

BOILER COMPOUNDS.

Boiler compounds are widely used in regions where hard waters abound, but treatment within the boiler should be given only when it is impossible to purify the supply beforehand or when the supply is relatively pure and requires only minor correction. If previous purification is not practicable some feed waters can be improved by judicious addition of chemicals. Many substances, ranging from flour, oatmeal, and sliced potatoes to barium and chromium salts, have been recommended for such use, but only a few have proved to be really efficient. These substances have been classified [1] according to their action within the boiler. Those that attack chemically the scaling and corroding constituents precipitate incrusting matter and neutralize acids. Soda ash, the commercial form of sodium carbonate, containing about 95 per cent Na_2CO_3, is the most valuable substance of this character, because it is cheap and its use is attended with the least objectionable results. Tannin and tannin compounds are also used for the same purpose. The addition of limewater to the feed to prevent corrosion and to obviate foaming has been recommended,[2] and it is probable that it would improve waters high in organic matter and very low in incrustants. Such practice increases the incrustants in proportion to lime added but prevents corrosion. Soda ash neutralizes free acids, precipitates the incrusting ingredients as a softer, more flocculent material, which is more easily removed from the boiler, and increases the foaming tendency of the water by increasing its content of dissolved matter. The proper amount to be used depends on the chemical composition of the water and the style of the boiler.

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[1] Cary, A. A., The use of boiler compounds: Am. Machinist, vol. 22, pt. 2, p. 1153, 1899.

[2] Palmer, Chase, Quality of the underground waters in the Blue Grass region of Kentucky: U. S. Geol. Survey Water-Supply Paper 233, p. 187, 1909.

The second class of boiler compounds comprises those that act mechanically on the precipitated crystals of scale-making matter soon after they are formed, surrounding them and robbing them of their cement-like action. Glutinous, starchy, and oily substances belong to this class, but they are not now used to any considerable extent because they thicken and foul the water more than they prevent the formation of hard scale.

The third class comprises compounds that act mechanically like those of the second class and also partly dissolve deposited scale, thus loosening it and aiding in its ready removal. Of these, kerosene is very effective, but graphite is believed to be still better.

Many boiler compounds possessing or supposed to possess one or more of the functions just described are on the market and are widely sold. Some are effective and some are positively injurious. Most of them depend for their chief action on soda ash, petroleum, or a vegetable extract, but all are costly compared with lime and soda ash. Boiler compounds can not reduce the amount of scale and may increase it. Their only legitimate functions are to prevent corrosion and deposition of hard scale and to remove accumulations of scale that have become attached to the boiler. Every engineer should bear in mind that steam boilers are costly and that fuel and boiler repairs are costly and should hesitate to add substances to his feed water without competent advice as to their effect. It is far more economical to have the water supply analyzed and to treat it effectively by well-known chemicals in proper proportion, either within or without the boiler, than to experiment with compounds of unknown composition.

NUMERICAL STANDARDS.

Stabler's excellent mathematical discussion of the quality of waters with reference to industrial uses [1] contains several formulas by which the effect of waters may be computed. They have been recalculated in order to obtain the estimates in parts per million. The terms involving iron, aluminum, and free acids have been omitted because these substances are too scarce to call for consideration in such approximate rating; and the terms involving sodium and potassium have been united for simplicity.

(1) $s = Sm + Cm + 2.95\ Ca + 1.66\ Mg$

(2) $h = SiO_2 + 1.66\ Mg + 1.92\ Cl + 1.42\ SO_4 - 2.95\ Na$

(3) $f = 2.7\ Na$

(4) $c = 0.0821\ Mg - 0.0333\ CO_3 - 0.0164\ HCO_3$.

These equations express numerically some of the relations that have been discussed in the preceding sections on scale, corrosion, and

[1] Stabler, Herman, Some stream waters of the western United States, with chapters on sediment carried by the Rio Grande and the industrial application of water analyses: U. S. Geol. Survey Water-Supply Paper 274, p. 165, 1911. See also Eng. News, vol. 60, p. 355, 1908.

foaming. Sm, Cm, SiO_2, Ca, Mg, Na, Cl, SO_4, CO_3, and HCO_3 represent the amounts in parts per million, respectively, of suspended matter, colloidal matter (oxides of silicon, iron, and aluminum), silica, calcium, magnesium, alkalies, chlorine, sulphate, carbonate, and bicarbonate.

Formula 1 gives the amount of scale (s) that would probably be formed from the water under ordinary conditions of boiler operation; as the ground waters of San Joaquin Valley are practically clear, Sm is equal to zero. Cm has been given a value of 50 for waters not exceeding 400 parts of total solids and 30 for other waters, and these values may be considered large enough for safety.

Formula 2 gives the amount of hard scale forming ingredients (h). The ratio $\frac{h}{s}$ expresses the relative hardness of the scale. If $\frac{h}{s}$ is greater than 0.5 the scale may properly be called hard; if it is less than 0.25 the scale may properly be called soft.

Scale (s) has been estimated from the data of the field assays by adding to total hardness (H) the values of Cm used in formula 1 ($s = Cm + H$). As H theoretically equals $2.5\ Ca + 4.1\ Mg$, and the last two terms of equation 1 are $2.95\ Ca + 1.66\ Mg$, the unknown but variable ratio between calcium and magnesium introduces an uncertain error. Estimates of the scale-forming constituents are, however, always approximate, and experience indicates that this computed value is accurate enough for relative ratings.

Formula 3 gives the amount of the foaming ingredients (f), as estimated from the probable content of alkali salts. The value of sodium (Na) computed by the formula on page 57 has been used in computing the amount of the foaming ingredients from the results of the field assays.

Formula 4 has been used to calculate the corrosive tendency of the water (c). As can be readily seen from the coefficients, it expresses the relation between the reacting values of magnesium and the radicles involving carbonic acid (p. 62). If c is positive, the water is corrosive. If $c + 0.0499\ Ca$, the reacting value of calcium, is negative, the mineral constituents will not cause corrosion, but whether organic matter or electrolysis will cause it is uncertain. If $c + 0.0499\ Ca$ is positive corrosion is uncertain. These conditions of reaction may be restated to conform to the data of the field assays thus: If $0.033\ CO_3 + 0.016\ HCO_3$ equals or exceeds $0.02\ H$ the mineral constituents will not cause corrosion. If $0.004\ H$ exceeds $0.033\ CO_3 + 0.016\ HCO_3$ the water is corrosive. One-fiftieth of the total hardness ($0.02\ H$) is equivalent to the reacting value of calcium and magnesium, and H divided by 230 ($0.004\ H$) is equivalent to the reacting value of magnesium on the assumption that $Ca = 6\ Mg$, a ratio in which magnesium is given its smallest probable value in relation to

calcium. The reacting values of carbonate and bicarbonate are represented, respectively, by 0.033 CO_3 and 0.016 HCO_3, the coefficients of which are obtained by dividing the valence of each radicle by its molecular weight.

After these three attributes of boiler feed have been computed rating the water is largely a matter of judgment based on experience. The committee on water service of the American Railway Engineering and Maintenance of Way Association has offered two classifications by which waters in their raw state may be approximately rated, but, as the report states, "it is difficult to define by analysis sharply the line between good and bad water for steam-making purposes." Table 11 gives these classifications with the amounts transformed to parts per million.

TABLE 11.—*Ratings of waters for boiler use according to proportions of incrusting and corroding constituents and according to foaming constituents.*

Incrusting and corroding constituents.			Foaming constituents.		
Parts per million.		Classification.[a]	Parts per million.		Classification.[b]
More than—	Not more than—		More than—	Not more than—	
....	90	Good.	....	150	Good.
90	200	Fair.	150	250	Fair.
200	430	Poor.	250	400	Bad.
430	....	Bad.	400	....	Very bad.

[a] Am. Ry. Eng. and Maintenance of Way Assoc. Proc., vol. 5, p. 595, 1904.
[b] Idem, vol. 9, p. 134, 1908.

The classification by incrusting and corroding constituents has been applied to the computations of scale-forming ingredients (s) in the analytical tables accompanying this report. The quantity of foaming ingredients (f) should always be considered in conjunction with the probable amount of scale or sludge that would be formed, the hardness of the scale, and the tendency toward corrosion. These ratings result in a classification rather more rigid than that usually reported by chemists of railroads in California, and for that reason those who are thoroughly familiar with local conditions and with the chemistry of water will doubtless prefer to disregard the descriptive terms of the classification and to draw their own conclusions regarding the quality of the waters from the figures representing scaling, foaming, and corrosion. The classifications are given principally for the aid of those not thoroughly familiar with such matters, and rather to indicate the limits of usefulness than to define rigidly the value of the waters.

No matter how low a water may be in undersirable constituents it is poor economy to use it if it is much poorer in quality than the average water of the region in which it occurs. On the other hand,

if the best available supply is poor the economy of purifying it even at large expense is obvious. Along the Atlantic Coast, where waters containing less than 100 parts per million of incrusting ingredients are extremely common, a supply carrying 200 parts of such substances would not be considered fair for boiler use. Throughout most of Mississippi Valley, however, such a supply would be considered good, because in that region natural waters not exceeding 100 parts in scale-forming constituents are rare. This variance in local standards is well illustrated by the opinions on the two sides of San Joaquin Valley as to what constitutes a good boiler water, and because of it numerical standards should be interpreted relatively not literally. At the same time any classification by nominal ratings must be applied absolutely if the terms are to have comparative significance outside the region where the waters exist. Waters of poor quality can be improved by treatment in softening plants. How bad a water may be used without treatment depends on the cost of softening the water and the relative saving effected by the use of the softened water. A report[1] of the committee on water service of the American Railway Engineering and Maintenance of Way Association sets forth the factors involved. The benefits include the saving in boiler cleaning, repairs, and fuel, the decrease in the time during which the boilers must be withdrawn from service for cleaning and repairs, the decreased depreciation of the boilers, and the value of the materials removed by softening. The cost of softening includes the cost of labor and power for the softening apparatus, the cost of softening chemicals, the interest on the cost of installation, depreciation in the value of the softening plant, and the waste in changing boiler feed due to increased foaming tendency.

In locomotive service, it is in general economical to treat waters containing 250 to 850 parts per million of incrustants and to treat those containing less than 250 parts if the scale formed contains much sulphate.[2] As the incrusting solids may commonly be reduced to 80 or 90 parts per million, the economy of treating boiler waters deserves consideration in a region where many supplies contain 300 to 500 parts per million of incrusting matter.

The amount of mineral matter that makes a water unfit for boiler use depends on the combined effect in boilers of the softening reagents used with such waters and of the constituents not removed by softening. Sodium salts added to remove incrustants or to prevent corrosion increase the foaming tendency, and this increase may be great enough to render a water useless for steaming. It is not of much benefit to soften a water containing more than 850 parts per million of nonincrusting material and much incrusting sulphate.[2] Trouble

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[1] Am. Ry. Eng. and Maintenance of Way Assoc. Proc., vol. 8, p. 601, 1907.
[2] Idem, vol. 6, p. 610, 1905.

from priming in locomotive boilers begins at a concentration of about 1,700 parts per million of foaming constituents, and the limit of safety for stationary boilers is reached at a concentration of about 7,000 parts. Though waters containing as high as 1,700 parts per million of foaming constituents have been used, it is usually more economical to incur considerable expense in replacing such supplies by better ones.

WATER FOR MISCELLANEOUS INDUSTRIAL USES.

GENERAL REQUISITES.

Many articles are affected by the ingredients of the water used in their manufacture and can be improved by its purification. If by the same process the boiler efficiency of the factory can be increased the expense is often justified when it would not be warranted merely by the increased value of the product. This observation applies particularly to paper, pulp, and strawboard mills, laundries, and other establishments where large quantities of water are evaporated to furnish steam for drying, and to ice factories and similar plants where distilled water is required.

Besides its use for steam making water plays a specific part in many manufacturing processes. In paper mills, strawboard mills, bleacheries, dye works, canning factories, pickle factories, creameries, slaughterhouses, packing houses, nitroglycerin factories, distilleries, breweries, woolen mills, starch works, sugar works, canneries, glue factories, soap factories, and chemical works water becomes a part of the product or is essential in its manufacture. In most of these establishments the principal function of the water is that of a cleansing agent or a vehicle for other substances, and therefore a supply free from color, odor, suspended matter, microscopic organisms, and especially from bacteria of fecal origin, and fairly low in dissolved substances, especially iron, is with few exceptions satisfactory. But water hygienically acceptable is necessary where it comes into contact with or forms part of food materials, as in the making of beverages, sugar, and dairy or meat products. As ideal waters for any use are rare, the manufacturer must ascertain what degree of freedom from impurities is necessary to prevent injury to his machinery or to his output and whether the cost of obtaining such purity is counterbalanced by decreased cost of production and increased value of product.

EFFECTS OF DISSOLVED AND SUSPENDED MATERIALS.

The effects in some industries of the substances most commonly found in water are outlined in the following pages, the object being to offer approximate standards for classification.

FREE ACIDS.

Free mineral acids, such as the sulphuric acid in drainage from coal mines or the hydrochloric acid in the effluents of some industrial establishments, are especially injurious and nearly always have to be neutralized before the waters containing them can be used industrially. In paper mills, cotton mills, bleacheries, and dye works waters containing a measurable amount of free mineral acid decompose chemicals, streak and rot fabrics, and corrode and rapidly destroy metal screens, strainers, and pipes.

SUSPENDED MATTER.

Suspended matter in surface waters may be of vegetable, mineral, or animal origin, as it consists of particles of sewage, bits of leaves, sticks and sawdust, and sand and clay. The fine silt so common in rivers of the West is largely derived from clay. Few well waters contain suspended animal or vegetable matter, but many carry finely divided sand and clay, and many become turbid by precipitation of dissolved ingredients. Suspended matter is objectionable in all processes in which water is used for washing or comes into contact with food materials, because it is likely to stain or spot the product. Suspended matter due to precipitated iron is especially injurious even in small amount. Suspended vegetable or animal matter liable to decomposition or to partial solution is much more objectionable, even in small amount (10 to 20 parts per million), than equal quantities of mineral matter. For these reasons water should be freed from suspended matter before being used for laundering, bleaching, wool scouring, paper making, dyeing, starch and sugar making, brewing, distilling, and similar processes. In making the coarser grades of paper, such as strawboard, a small amount of suspended matter is not especially injurious, but for the finer white and colored varieties clear water is essential.

COLOR.

Color in water is due principally to solution of vegetable matter. Materials bleached, washed, or dyed light shades in colored water are likely to become tinged. Highly colored waters can be used in making wrapping or dark-tinted papers but not in making the white grades, and paper manufacturers are put to great expense for water purification on that account. The lower waters are in color, therefore, the more desirable they are for use in bleacheries, dye works, paper mills, and other factories where brown tints in the products are undesirable.

IRON.

Iron is the most undesirable dissolved constituent, and its presence in comparatively small quantities necessitates purification. Many ground waters contain 1 to 20 parts per million of iron, which may

be precipitated by exposure to the air and by release of hydrostatic pressure, causing the waters to become turbid, and many such waters develop rusty-looking gelatinous growths that may interfere in industrial operations. In all cleansing processes, especially if soap or alkali is used, precipitated iron is likely to cause rusty or dull spots. In contact with materials containing tannin compounds iron forms greenish or black substances that discolor the product. Therefore many waters containing amounts even as small as 1 or 2 parts per million of iron have to be purified before they can be used industrially. In water for dye works iron is especially objectionable and commonly prevents the use of the water without purification.[1] Iron in the water supply of paper mills may be precipitated on the pulp, giving a brown color, or during sizing or tinting, giving spotty effects. Water containing much iron can not be used in bleaching fabrics because salts that spot the goods are formed. The dark-colored compounds that iron forms with tannin discolor hides in tanning and barley in malting, and give beer a bad color, odor, and taste.[2]

CALCIUM AND MAGNESIUM.

Calcium and magnesium are similar in their industrial effects. In water their amounts bear a more or less definite relation to each other, most waters carrying 10 to 50 per cent as much magnesium as calcium. Both are precipitated on whatever is boiled in water containing them, forming a deposit that may interfere with later operations. They also decompose equivalent amounts of many chemicals employed in technical operations, causing waste and forming alkaline-earth compounds that interfere with the later treatment of fabrics. These are the strongest incentives to preliminary softening. Some of the chemicals used to disintegrate the fibers in making pulp are consumed by the calcium and magnesium in the water supply, though the loss from this source is not nearly so great as that which occurs later when the resin soap used in sizing the paper is decomposed by the calcium and magnesium. The insoluble soaps thus created do not fix themselves on the fibers, but form clots and streaks. Similar decomposition of valuable cleansing materials and subsequent deposition of insoluble compounds take place in laundering, wool scouring, and similar processes. In the manufacture of soap, calcium and magnesium form with the fatty acids curdy precipitates that are insoluble in water and therefore have no cleansing value. They interfere with many dyeing operations, neutralizing chemicals and changing the reactions of the baths, besides forming insoluble compounds with many dyes. Highly calcareous waters can not be used for boiling the grain in distilleries because they hinder proper action by causing the deposition of

[1] Sadtler, S. P., A handbook of industrial organic chemistry, p. 483, Philadelphia, 1900.
[2] De la Coux, M. A. J., L'eau dans l'industrie, pp. 187, 232, Paris, 1900.

alkaline-earth salts on the particles of grain, nor for diluting spirits because they cause turbidity.[1] Very soft water, on the other hand, is said to be undesirable in paper mills for loading papers with any form of calcium sulphate because such waters dissolve part of the loading materials.[2] Probably waters high in chlorides would also be bad for this purpose, because chlorides increase the solubility of calcium sulphate.

CARBONATE.

The effects of carbonate and bicarbonate in waters used in industrial processes are commonly not differentiated. It is not unusual to estimate the combined carbonic acid and to state it as the carbonate without distinguishing between carbonate and bicarbonate, though in many natural waters the carbonate radicle is absent and the combined carbonic acid is in the form of bicarbonate. If hard waters proportionately high in carbonate and low in sulphate are boiled the bicarbonate radicle is decomposed, free carbonic acid is given off, and the greater part of the calcium and magnesium is precipitated. Consequently waters of that character are generally more desirable for industrial operations than waters high in sulphate and low in carbonate, whose hardening constituents are not greatly reduced by boiling. In beer making waters high in carbonate are said to produce dark-colored beers with a pronounced malt flavor because the carbonate increases the solubility of the nitrogenous bodies, whereas waters high in sulphate yield pale beers with a definite hop flavor because the sulphate reduces the solubility of the malt and the coloring matters.[3]

SULPHATE.

The influence of sulphate in beer making has been noted. Hard waters with sulphate predominating are desirable in tanning heavy hides, because they swell the skins, exposing more surface for the action of the tan liquors.[4] Sulphate interferes with crystallization in sugar making by increasing the amount of sugar retained in the mother liquor.

CHLORINE.

High chlorine is usually accompanied by high alkalies. Appreciable amounts of chlorine are injurious in many industrial processes. Beverages and food products, of course, can not be treated with waters very high in chlorine without becoming salty. In tanning, chlorides cause the hides to become thin and flabby.[4] Animal char-

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[1] De la Coux, M. A. J., L'eau dans l'industrie, p. 251, Paris, 1900.

[2] Cross, C. F., and Bevan, E. J., A textbook of paper making, p. 294, New York, 1900.

[3] Brewing water, its defects and remedies, p. 19, American Burtonizing Co., New York, 1909. Also De la Coux, M. A. J., op. cit., p. 169.

[4] Parker, H. N., and others, The Potomac River basin: U. S. Geol. Survey Water-Supply Paper 192, p. 194, 1907.

coal used in clarifying sugar is robbed of its bleaching power by absorption of salt. The quality of sugars is affected by chloride-bearing waters, because saline salts are incorporated in the crystals.[1] In the preparation of alcoholic beverages chlorides in large amount prevent the growth of the yeast and interfere with the germination of the grain. The only commercially developed way of removing chlorine from water is distillation. As the cost of this process has been greatly reduced by use of multiple-effect evaporators, it is worth consideration where chloride-bearing waters must be used.

ORGANIC MATTER.

Organic matter of fecal origin is, of course, dangerous in any water that comes into contact with food products, and water so polluted should be purified before being used. Care in this respect is particularly necessary in creameries, slaughterhouses, canneries, pickle factories, distilleries, breweries, and sugar factories. Organic matter not necessarily capable of producing disease is further undesirable in industrial supplies because it induces decomposition in other organic materials, like cloth, yarn, sugar, starch, meat, or paper, rotting and discoloring them, and because it causes slime spots on fabrics by supporting algæ growths.

HYDROGEN SULPHIDE.

Hydrogen sulphide (H_2S), a gas with an odor like that of rotten eggs, occurs dissolved in some ground waters. It is corrosive even in small quantities, and it also injures materials by discoloring and rotting them.

MISCELLANEOUS SUBSTANCES.

Silica and aluminum are usually not present in sufficient quantity appreciably to affect any industrial process, except those in which water is evaporated. Large quantities of sodium and potassium, by adding to the amount of dissolved matter, are objectionable in some manufacturing operations. Phosphates, nitrates, and some other substances not noted in this outline interfere with industrial chemical reactions, but they are present in few natural waters in sufficient quantity to have noticeable effect.

WATER FOR DOMESTIC USE.

PHYSICAL QUALITIES.

Entirely acceptable domestic supplies are free from suspended matter, color, odor, and taste and are fairly cool when they reach the consumer. The more nearly waters fulfill these conditions the more satisfactory they are for general use. Suspended mineral matter clogs pipes, valves, and faucets, and growths of microscopic plants

[1] De la Coux, M. A. J., op. cit., p. 152.

suspended in water frequently cause odors and stains. The outlets of some artesian wells in San Joaquin Valley are surrounded by growths of microscopic organisms, which form tufts or layers in pipes and well casings and sometimes clog them. Detached particles escape through faucets, giving the water an unsightly appearance and staining clothes washed in it. So far as known, such growths in tanks and mains do not cause disease, but they often impart unpleasant odors that make the water objectionable. True color is usually due to dissolved vegetable matter and causes serious objection only when it exceeds 20 to 30 parts per million.

In general, the well waters of this area are satisfactory in respect to suspended mineral matter and color. Finely divided material from quicksands enters some driven wells, but such trouble is not so serious as it is in other parts of the country. A few waters, especially those containing iron, develop a turbidity of 10 to 30 parts per million on exposure to the air by precipitating dissolved matter, and such condition gives rise to apparent though not to real color. The only ground waters possessing much real color were found near the north end of Tulare Lake, where buried peat beds of old swamps probably contribute the organic matter that causes the color.

The odor most commonly noticed in the ground waters of the valley is that of hydrogen sulphide, especially in the area where artesian wells yield notable quantities of natural gas. According to analyses quoted by Watts [1] the gas from wells at Stockton comprises about 25 per cent nitrogen, 12 per cent hydrogen, and 60 per cent hydrocarbon illuminants estimated as marsh gas (CH_4), and probably this composition represents the general character of the gas throughout the valley, though the proportions of the substances may differ locally. The content of hydrogen sulphide is doubtless very small, but minute quantities of it are sufficient to cause appreciable odor. This smell, nauseating to some people, can usually be removed by spraying or splashing the water.

BACTERIOLOGICAL QUALITIES.

Before a water is used for domestic purposes there should be reasonable certainty that it is free from disease-bearing organisms and that it can be guarded against all chances of infection. The disease germs most commonly carried by water are those of typhoid fever. The bacilli enter the supply from some spot infected by the discharges of a person sick with this disease, and, though comparatively short lived in water, they persist in fecal deposits and retain their power of infection for remarkable lengths of time. Consequently, water from lakes and streams draining from population centers or

[1] Watts, W. L., The gas and petroleum yielding formations of the central valley of California: California State Mining Bur. Bull. 3, p. 75, 1894.

from irrigated fields should not be used for drinking without purification. Wells should be so located as to be guarded against the entrance of filth of any kind, either over the top or by infiltration. Pumps and piping in the system should also be protected. Water from a carefully cased well more than 20 or 30 feet deep is acceptable if the well is located at a reasonable distance from privies, cesspools, and other sources of pollution. Many open dug wells and pits constructed as reservoirs around the tops of casings are exposed to fecal contamination from above or through cracks in poorly built side walls. Care should be taken that the casings of deep wells do not become leaky near the surface of the ground so as to allow pollution to enter. As a matter of ordinary precaution the ground should be kept clean and water should not be allowed to become foul or stagnant near any well, no matter how deep. If shallow dug wells are necessary they should be constructed with water-tight walls extending as far as practicable into the well and also a short distance above ground. The floor or curbing should be water-tight, and pumps should be used in preference to buckets for raising the water. Every possible precaution should be taken to prevent feet scrapings and similar dirt from getting into the well. Ground water is not only less likely to become contaminated when protected from surface washings, air, and light, but it keeps better and is less likely to develop microscopic plants that give it an unpleasant taste.

CHEMICAL QUALITIES.

The amounts of dissolved substances permissible in a domestic supply depend much on their nature. No more than traces of barium, copper, zinc, or lead should be present, because these substances are poisonous; however, their occurrence in measurable amounts in ordinary waters is so rare that tests for them are not usually made. Any constituent present in sufficient amount to be clearly perceptible to the taste is objectionable. Water containing 2 parts per million of iron is unpalatable to many people and may cause trouble by discoloring washbowls and tubs and by producing rusty stains on clothes. Tea and coffee can not be made satisfactorily with water containing much iron because a black inky compound is formed. Four or five parts of hydrogen sulphide makes a water unpleasant to the taste, and this gas is objectionable also because it corrodes well strainers and other metal fittings. The amounts of silica and aluminum ordinarily present in well waters have no special significance in relation to domestic supply.

Approximately 250 parts of chlorine makes a water "salty," and less than that amount causes corrosion. Where the chlorine content runs as low as 5 or 10 parts in normal waters unaffected by animal pollution the amount of chlorine is frequently taken as a

measure of contamination. But the establishment of isochlors, or lines of equal chlorine, in San Joaquin Valley would be of little sanitary value, because many of the ground waters dissolve so much chlorine from the silt that the small changes caused by animal pollution are completely masked.

Calcium and magnesium are the chief causes of what is known as the hardness of water. This undesirable quality is indicated by increased soap consumption and by deposition on kettles of scale composed almost entirely of calcium, magnesium, carbonate, and sulphate. Calcium and magnesium, forming with soap insoluble curdy compounds that have no cleansing value, prevent the formation of a lather until these two basic radicles have been precipitated. Hardness is commonly measured by the soap-consuming capacity of a water expressed as an equivalent of calcium carbonate ($CaCO_3$), and it can be determined by actual testing with a standard solution of soap or can be computed from the amounts of calcium (Ca) and magnesium (Mg) by means of the following formula:

$$\text{Total hardness as } CaCO_3 = 2.5\ Ca + 4.1\ Mg.$$

If, as Whipple states,[1] 1 pound of ordinary soap would soften only about 24 gallons of water having a total hardness of 200 parts per million, it can readily be seen that the hardness of water is of intimate concern, especially in the west side, where waters as hard as 300 to 1,000 parts are common. Soda ash (sodium carbonate) is used to "break" or soften hard water in order to save soap. Some large cities in other States have found it advisable to soften their public supplies instead of leaving that task to the individual consumer.

MINERAL MATTER AND POTABILITY.

The lower waters are in mineral content the more acceptable they are as sources of supply, yet the amount of dissolved substances that can be tolerated in drinking water is much greater than that allowable in city supplies, for which hardness, corrosion, pipe clogging, and general utility have to be considered. Though there are certain limits above which the common ingredients are intolerable, these limits are not only difficult to ascertain but are also likely to shift. A normal water is not a pure solution of one salt, whose physiologic effect can be measured, but an indeterminate mixture of solutions of several salts whose effects are not easily differentiated. Further, though all animals select for drinking waters that are lowest in solids and avoid those that are highest, the same animals, when transported to districts of poor water, accustom themselves to supplies of far greater mineral content than those which before they would not

[1] Whipple, G. C., The value of pure water, p. 26, New York, 1907.

touch. Consequently any general limits that may be assigned to the various mineral ingredients must be regarded as extremely flexible. The truth of this statement may be more fully appreciated by consideration of the data in Table 12, in which the analyses are grouped according to the chemical character of the waters and are arranged in each group in descending order of strength.

TABLE 12.—*Mineral matter in certain waters.*

[Parts per million.]

No.	Carbonate radicle (CO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total solids.	Calcium and magnesium (Ca+Mg).	Sodium and potassium (Na+K).	Character of water.
1....	43	Tr.	4,310	2,800	7,489	966	1,550	Na-Cl.
2[a]...	360	1,560	1,300	....	5,000	....	....	Do.
3....	75	5	1,740	910	3,600	300	830	Do.
4....	46	328	1,520	506	3,600	170	1,030	Do.
5....	54	390	1,060	490	2,800	160	750	Do.
6....	200	5	279	31	872	11	320	Do.
7[a]...	110	2,300	800	....	4,900	....	....	Na-SO_4.
8....	100	1,810	160	1,130	3,200	380	580	Do.
9....	362	1,640	460	1,760	4,100	150	600	Do.
10....	97	800	150	560	1,700	190	320	Do
11....	73	430	75	83	940	25	300	Do.
12[a]...	410	620	500	....	2,470	....	....	Na-CO_3.
13....	963	Tr.	492	660	2,452	191	750	Do.
14....	208	Tr.	135	47	750	15	240	Do.
15....	100	Tr.	64	71	350	24	86	Do.
16....	75	1,680	145	1,280	2,900	400	400	Ca-SO_4.
17....	72	1,380	150	1,320	2,500	440	220	Do.
18....	60	1,380	135	1,100	2,400	370	305	Do.
19....	74	895	85	720	1,700	228	208	Do.
20....	38	9	4	50	169	16	16	Ca-CO_3.

[a] From a manuscript report by Herman Stabler on the underground waters of Carson Sink, 1904. The other analyses were made for this report.

The first group in Table 12 represents sodium chloride waters; that is, waters in which alkalies and chlorides predominate. Analysis No. 1, of water from a gas well in Stockton, represents a solution of the chlorides of calcium, magnesium, sodium, and potassium with little else. The water contains 4,310 parts per million of chlorine, and it is so salty that it is nauseating. The water represented by the next analysis has been used by the owner's family several years for all domestic purposes, but visitors object to it and consider it disagreeable to drink. No. 3 is the analysis of water from a deep well near Stockton that was formerly used as a source of domestic supply but has been abandoned. Nos. 4 and 5 are analyses of water from artesian wells near San Joaquin River, and though both supplies taste disagreeably salty to persons not accustomed to them, they are regularly used for drinking, cooking, and washing. Two gallons of the former water contains about as much common salt as a pound of uncooked ham. No. 6, the test of the supply of a very deep artesian well on the west side not far from Lemoore, indicates a water much lower in chloride but higher in carbonate or "black alkali." As the farm on which the well is situated was not occupied informa-

tion regarding the value of the water as a constant beverage could not be obtained. It contains much gas and would be distasteful on that account; otherwise, however, it differs from that represented by No. 14 only in being somewhat higher in chloride and alkalies.

More strongly mineralized alkaline sulphate waters are drunk. The first one (see analysis No. 7), from a well in Carson Sink, was used when necessary, but the domestic supply was commonly hauled from another source several miles away. The water represented by analysis No. 8, which has been used for all domestic purposes for several years on a ranch west of Mendota, carries 1,800 parts of sulphate and exceeds 3,000 in total solids. It has a distinct taste and drinking a quart of it would be equivalent to taking somewhat less than a minimum dose of Glauber's salt. The water corresponding to No. 9 was used in the cook wagon and for watering the stock about one year on a ranch near Tulare Lake, but it was considered "alkali" water, and the domestic supply is now obtained from a deeper and much better well. Chloride and carbonate, as well as sulphate, however, are notably high in this water. The waters corresponding to 10 and 11 are used for all domestic purposes, though they have a distinct taste. The former is one of a battery of wells that have been the exclusive supply of a family for three years, and the latter is the municipal supply of Mendota.

The examples in the next group prove that less alkaline carbonates can be tolerated. The first analysis (No. 12) shows a water also high in chloride but not excessive in sulphate. This water has a color of 130, and it obviously carries much "black alkali." A party of men accustomed to alkali was so badly afflicted with diarrhea after drinking this water that work had to be stopped until another supply could be obtained. No. 13 shows nearly double the amount of carbonate but no sulphate. This water supplies a trough for stock, but it was evidently repugnant to the cattle, and current report in the neighborhood is to the effect that water from wells of the same depth "kills hogs," a phrase that seems to express the acme of undesirability. The mixture of alkaline carbonates and chlorides with the former predominating, indicated by test No. 14, has been used many years, but it is much lower in carbonate than the preceding two. The water listed under No. 15, the city supply of Stockton for many years, is drunk both by the inhabitants of the city and by visitors without harmful effect.

Though the next four are designated calcium sulphate waters the alkalies also are high, and, furthermore, application of the term calcium necessarily implies the presence of magnesium in amounts ranging from 10 to 40 per cent of the total calcium and magnesium given in the seventh column of the table. The water corresponding to No. 16 can not be used for cooking, and herders object to it so strongly

that the drinking supply is hauled 8 miles from the well represented by No. 17, which carries 300 parts less of sulphate and about half as much sodium and potassium. Analysis No. 18, which is similar to No. 17, is of a water that has been used more than 10 years for cooking and drinking by one man. These three waters tasted unpleasantly strong to the writer and seemed to increase thirst instead of quenching it. Though the water represented by analysis No. 19 is lower in sulphate than the preceding ones of this group, it is strongly mineralized. It is the hotel supply at Huron, where it is used for all purposes.

Calcium carbonate waters are extremely common, but it is unusual for them to be so highly mineralized as those of other classes. The representative of this type, indicated by test No. 20, is low in total solids and is entirely acceptable for drinking and cooking.

The immediate consequence of drinking waters too high in mineral content is usually diarrhea. Many persons at first afflicted with this trouble become accustomed to the new supply and acquire what may be termed immunity. Whether other disorders result from the continued drinking of such waters is not known; and it is equally uncertain whether cattle and horses that so commonly are reported to have been killed by drinking strong mineral water were killed by the purging produced by the mineral matter in the water or by excessive consumption of water itself. It would appear from the data in Table 12 and the comments on it that alkaline carbonates are most injurious and alkaline sulphates least injurious and that alkaline chlorides occupy an intermediate position. This arrangement corresponds to the order of the same substances in reference to their toxic effect on plants. The most striking feature is that the amounts of mineral matter in most of these waters is much greater than that ordinarily considered permissible in drinking water. Waters exceeding 300 parts per million of carbonate, 1,500 parts of chloride, or 2,000 parts of sulphate are apparently intolerable to most people. These limits fortunately are far beyond the points where the substances in solution are clearly perceptible to the ordinary taste. In conclusion it can not be too emphatically stated that the information on this subject is fragmentary and uncertain and that any limits of mineral tolerance are modified by individual idiosyncrasy.[1]

INTERPRETATION OF FIELD ASSAYS IN RELATION TO POTABILITY.

CHEMICAL CHARACTER.

The total amount of mineral matter and the nature of the chief constituents in a water comprise the essential information for judging its potability in respect to mineral ingredients. Though nitrates,

[1] For further data see Dole, R. B., Concentration of mineral water in relation to therapeutic activity: U. S. Geol. Survey Mineral Resources, 1911, pt. 2, pp. 1175–1192, 1912.

phosphates, sulphides, and other substances occur in some waters they may usually be disregarded in interpretation or their insignificance verified by a few laboratory analyses. Silica is usually present in colloidal form and it is relatively constant in quantity.

Calcium and magnesium are similar in many effects and they vary in amount together, calcium usually being the greater. Sodium and potassium are so similar in effect that they are seldom separated in industrial analyses but are reported together as sodium. Carbonate and bicarbonate, representing more or less conventionally different conditions of carbonate in equilibrium, may be considered together under the common term of carbonate (CO_3), to which bicarbonate is translated by dividing by 2.03. These groupings, rendered possible by the usual mode of occurrence of these substances and by their effects, greatly simplify classification of waters that have been assayed. Direct estimates are made of carbonate, sulphate, and chloride, the three principal acid radicles. The approximate amount of the alkaline earths, calcium and magnesium, can be computed from the total hardness; theoretically the total amount of these two bases must be between 40 per cent and 24 per cent of the total hardness expressed as $CaCO_3$; it usually lies between 37 per cent and 30 per cent, as the ratio of calcium to magnesium ranges from 7 to 1; therefore, one-third of the hardness is a reasonable estimate of the alkaline earths that will usually be in error less than 10 per cent. The alkalies, sodium and potassium, can be computed by the Stabler formula already noted (p. 57). These estimates and computations of the amounts of the chief acids and bases can then be used in applying the following classification:

Classification of water by chemical character.

$$\left.\begin{matrix}\text{Calcium (Ca)}\\ \text{Sodium (Na)}\end{matrix}\right\}\left\{\begin{matrix}\text{Carbonate } (CO_3).\\ \text{Sulphate } (SO_4).\\ \text{Chloride (Cl).}\end{matrix}\right.$$

The designation "calcium" indicates that calcium and magnesium predominate, and "sodium" that sodium and potassium predominate among the bases; the designation "carbonate," "sulphate," or "chloride" shows which acid radicle predominates. Combination of the two terms classifies the water by type, and tabulation of the classification can be abbreviated by use of the symbols. The appellation $Na–CO_3$, for example, indicates that sodium and potassium predominate among the bases and that carbonate or bicarbonate, or both, predominate among the acids, and that the water would yield on concentration and crystallization more sodium carbonate than any other salt, though this classification does not in any way show the amounts of the salts in solution.

The numerical preponderance of certain acid and basic radicles establishes the nature of many waters, but if further refinement in classification is desired comparison can be made of the reacting values of the radicles, which are the fundamental bases of the effect of the radicles. These values can be computed by multiplying the amount of each constituent by its valence and dividing the product by its molecular weight. The factors given in Table 13 can be used for that purpose. The factor for sodium may be used for the combined values of sodium and potassium. The reacting value of calcium and magnesium is nearly one-fiftieth of total hardness (H), as theoretically $H = 2.5\ Ca + 4.1\ Mg$, whence $\frac{H}{50} = 0.050\ Ca + 0.082\ Mg$.

TABLE 13.—*Factors for computing reacting values.*

Basic radicles.	Factor.	Acid radicles.	Factor.
Calcium (Ca)	0.0499	Carbonate radicle (CO_3)	0.0333
Magnesium (Mg)	.0821	Bicarbonate radicle (HCO_3)	.0164
Sodium (Na)	.0434	Sulphate radicle (SO_4)	.0208
Potassium (K)	.0255	Nitrate radicle (NO_3)	.0161
		Chlorine (Cl)	.0282

TOTAL SOLIDS.

Total solids can be computed from the data of a field assay in several ways, one of which is to calculate the probable amount of saline residue that would be produced by the acid radicles and to add thereto an arbitrary amount for silica, undetermined substances, and volatile matter. As potassium has the smallest reacting weight of the four common bases the assumptions that equal amounts of sodium and potassium are present and that calcium and magnesium are absent constitute an extreme condition representing a maximum saline residue; similarly, the assumptions that equal parts of calcium and magnesium are present and that the alkalies are absent constitute the condition representing a minimum saline residue. A formula based on an average between these two extremes gives an estimate of total solids (T. S.) within 15 per cent of the exact value for most natural waters.

$$T.\ S. = SiO_2 + 1.73\ CO_3 + 0.86\ HCO_3 + 1.48\ SO_4 + 1.62\ Cl.$$

The average content of silica (SiO_2) in most ground waters of San Joaquin Valley, according to available analyses, is about 30 parts per million in waters exceeding 400 parts of total solids and 50 parts in other waters. The estimate of solids should not be expressed more

closely than to the nearest 10 parts or with more than two significant figures, and it may be translated into words by the following rating:

TABLE 14.—*Rating of waters by total solids.*

Total solids (parts per million).		Classification.
More than—	Not more than—	
....	150	Low.
150	500	Moderate.
500	2,000	High.
2,000	....	Very high.

PURIFICATION OF WATER.

GENERAL REQUIREMENTS.

Purification of water is removal or reduction in amount of the substances that render waters in their raw state unsuitable for use. It is practiced on a large scale with one or more of three objects in view: First, to render the supply safe and unobjectionable for drinking; second, to reduce the amount of the mineral ingredients injurious to boilers; third, to remove substances injurious to machinery or to industrial products. The largest purification plants in this country have been constructed almost solely to render the waters potable; and some waters, when so purified, need no further treatment to make them suitable for steaming and for general industrial use. But many other waters are hard, and increased appreciation of the value of good water has resulted in demand for the removal of the hardening constituents also.

Only a few settlements in San Joaquin Valley have surface water supplies for domestic use, and extensive installation of filter plants is doubtful. But if municipalities in the region ever adopt river supplies, filtration will be necessary because of the widespread pollution of the streams by drainage from irrigated lands. The present general use of boiler compounds, however, even on the east side, indicates the advisability of water softening. Feed-water purification plants are now common on the west side, and future development of that region of highly mineralized waters will be accompanied by increase in the number of these plants.

Removal of bacteria, especially those causing disease, and removal of turbidity, odor, taste, and iron are the principal requirements in purification of a municipal supply, elimination of bacteria and suspended matter being the most important. The common methods of effecting such purification are slow filtration through sand and rapid filtration after coagulation, both methods usually being com-

bined with sedimentation.[1] The first process is known as "slow sand" filtration and the second as "mechanical" or "rapid sand" filtration. The efficiency of such filters is measured primarily by the ratio between the number of bacteria in the applied water and the number in the effluent. This figure, stated in percentage of removal, should be as high as 98, and it often reaches 99.8 per cent under normal conditions with a carefully operated filter of either kind.

Removal of scale-forming and neutralization of corrosive constituents are the chief aims in preparing water for steam making. For this two general methods are employed—cold chemical precipitation followed by sedimentation, and heating with or without chemicals, usually followed by rapid filtration. The first process is carried on in cold-water softening plants and the second in feed-water heaters.

METHODS OF PURIFICATION.

The requirements of the water supplies for industries are so varied that classification of purification methods is difficult. Water properly prepared for domestic and boiler use is suitable for most industrial establishments, and it is more economical for small manufacturers in large cities to obtain such water from the city mains than to maintain private supplies and purification apparatus. It is usually cheaper, however, for large factories to be supplied from separate sources, not only because of saving in actual cost of water but also because of the opportunity thus afforded of procuring water specially adapted to the needs of the factory. The common methods of industrial-water purification are those already mentioned, or combinations of them, modified to meet particular needs. In a few industrial processes, notably the manufacture of ice by the can system, water practically free from all dissolved and suspended substances is necessary and distilled water must be manufactured. Recent improvements in multiple-effect evaporators have greatly reduced the cost of distillation, so that it is now economical to distill for industrial and domestic use many waters heretofore considered too highly mineralized to be treatable. Many large factories, hotels, and even municipalities have installed multiple-effect stills.

Besides the four common systems of purification, many minor processes are used, sometimes alone, but more frequently as adjuncts to filters or softeners. Surface waters are screened through wooden or iron grids or through revolving wire screens to remove sticks and leaves before other treatment. Coarse suspended matter can be removed by rapid filtration through ground quartz or similar material, in units of convenient size, provided with arrangements for wash-

[1] For description of filters see Johnson, G. A., The purification of public water supplies: U. S. Geol. Survey Water-Supply Paper 315, 1913.

ing the filtering medium similar to those used in mechanical filters. Very turbid river waters may be first allowed to stand in large sedimentation basins in order to reduce the cost of operating the filters by preliminary removal of a large part of the suspended solids. Supplies undesirable only because of their iron content are aerated by being sprayed into the air or by being allowed to trickle over rocks or by other methods that cause evaporation of carbonic acid and absorption of oxygen, thus precipitating and oxidizing the iron in solution so that it can readily be removed by rapid filtration. Similar aeration is employed to evaporate and oxidize dissolved gases that cause objectionable tastes and odors.

Disinfection by ozone, copper sulphate, calcium hypochlorite, and many other substances kills organisms that may cause disease or impart bad odors and tastes. Purification of this character must be done with substances that destroy the objectionable organisms without making the water poisonous to animals. Calcium hypochlorite, sodium hypochlorite, and chlorine gas are used to disinfect drinking water, and treatment with these substances is now widely practiced either as an adjunct to filtration or as an emergency precaution where otherwise untreated supplies are believed to be contaminated. Disinfection by this method is not a substitute for purification by filtration, for it does not remove suspended matter nor appreciable amounts of color, organic matter, swampy tastes, or odors, and it does not soften water.[1] Natural purification of water is accomplished largely through biologic processes,[2] in which the organic matter is oxidized by serving as food for bacteria and objectionable organisms are destroyed by the production of conditions unfavorable to their existence. Action of this kind takes place in reservoirs and lakes, and it is also relied upon in many processes for the artificial purification of sewage.[3]

SLOW SAND FILTRATION.

Slow sand filtration consists in causing water to pass downward through a layer of sand of such thickness and fineness that the requisite removal of suspended substances is accomplished. The slow sand filter is also called the "continuous" and the "English" filter. On the bottom of a water-tight basin, commonly constructed of concrete, perforated tiles or pipes laid in the form of a grid are covered with a foot of gravel graded in size from 25 to 3 millimeters in diameter from bottom to top. A layer of fine sand, 3 to 4 feet deep, is put over the gravel, which serves only to support the sand.

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[1] Op. cit., p. 71.

[2] Hazen, Allen, Clean water and how to get it, p. 83, New York, 1907.

[3] Winslow, C.-E. A., and Phelps, E. B., Investigations on the purification of Boston sewage, with a history of the sewage-disposal problem: U. S. Geol. Survey Water-Supply Paper 185, 1906.

When water is applied on the surface, it passes through the sand and the gravel and flows away through the underdrain. The suspended materials, including bacteria, are removed by the sand, the action of which is rendered more efficient by the rapid formation of a mat of finely divided sediment on its surface. When this film has become so thick that filtration is unduly retarded, the water is allowed to subside and about half an inch of sand is removed, after which filtration is resumed. The sand thus taken off is washed to free it from the collected impurities and is replaced on the beds after they have been reduced about a foot in thickness by successive scrapings. As cleaning necessitates temporary withdrawal of filters from service, they are divided into units of convenient size, usually one-half to 1 acre each, so that the operation of the entire system may not be interrupted. Most modern filters are roofed and sodded, as this facilitates cleaning by preventing the formation of ice, permits work on the filter beds in all kinds of weather, inhibits algæ growths, and prevents agitation of the water by wind and rain.

The foregoing are the essential features of a slow sand filter, but several adjuncts render this system more efficient. A clear-water basin for the filtered supply, covered to prevent deterioration of the water, is provided in order that the varying rate of consumption may not unduly affect the rate of filtration. Clarification of turbid water is rendered more economical by allowing it to stand for one to three days, during which a large portion of the suspended matter is deposited, so that the time between sand scrapings is lengthened. In some plants roughing or preliminary filters consisting of beds of coarse sand or fine crushed stone are provided, through which the water flows 15 to 20 times as fast as through the sand filters, a very large proportion of the suspended matter being thus removed. Objectionable odors and tastes may be obviated by aeration before or after filtration. Killing the bacteria before filtration by use of chlorine or other germicides is also practiced.

Slow sand filtration removes practically all the suspended matter and the bacteria. Color is only slightly reduced and hardness is not changed. The process is specially adapted to waters low in color and suspended matter and slightly polluted. Very small particles of clay are not removed by these filters and waters carrying such particles only for short periods may be benefited by the occasional addition of a coagulant before filtration. It can readily be seen that the efficiency of this kind of filter depends largely on the character of the sand, as the ability to prevent the passage of suspended matter is governed by the size of the spaces between the sand particles. The rate of filtration depends on the average size of the sand particles, the thickness of the sand bed, the head of water, and the turbidity. Under ordinary conditions of operation in the United

States the rate of slow sand filtration of water previously subjected to sedimentation is 2,000,000 to 4,000,000 gallons per acre per day.

RAPID SAND FILTRATION.

The rapid sand filter is also known as the American filter, and until recently it was generally styled the "mechanical" filter, because of its contrivances for washing the sand. Its distinctive features are its use of a coagulant and its high rate of filtration. While the raw water is entering the sedimentation basin, which is smaller than that used with slow sand filters, it is treated with a definite proportion of some coagulant, which forms by its decomposition a gelatinous precipitate that unites and incloses the suspended material, including the bacteria, and absorbs the organic coloring matter. This combined action destroys color and makes suspended particles larger and therefore more readily removable. When aluminum sulphate, the coagulant most commonly used, is decomposed aluminum hydrate is precipitated and the sulphate radicle remains in solution, replacing an equivalent amount of the carbonate, bicarbonate, or hydrate radicle. One part per million of ordinary aluminum sulphate requires somewhat more than 0.6 part of alkalinity expressed as $CaCO_3$ to insure complete decomposition.[1] The natural alkalinity of many waters is sufficient to effect this reaction. If the alkalinity is not sufficient part of the aluminum sulphate remains in solution and good coagulation does not take place. Therefore lime or soda ash is added if the alkalinity is too low. The proper amount of aluminum sulphate to be used is determined by the amounts of color, organic matter, and suspended matter, and by the fineness of the suspended matter, and it is best ascertained by direct experimentation with the water to be purified. Much of the trouble in operating the earlier types of rapid filters has been caused by failure to produce a good "floc" or precipitation because of improper ratios of coagulant and alkalinity.

Ferrous sulphate instead of aluminum sulphate is used as a coagulant in some filtration plants. With this substance lime must be added in order to bring about proper coagulation.

The water, after having been mixed with the coagulant, is allowed to stand three or four hours in the sedimentation basin, where a large proportion of the suspended particles is deposited. It is then passed rapidly through beds of sand or ground stone to remove the rest of the suspended matter. Many filters now in use are built in cylindrical form 10 to 20 feet in diameter, and some are so designed that filtration can be hastened by pressure. The sand, 30 to 50 inches deep and coarser than that used in slow sand filters, rests on a metallic

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[1] Hazen, Allen, Report of the filtration commission of the city of Pittsburgh, p. 57, 1899.

floor containing perforations large enough to allow ready issue of the water, but small enough to prevent passage of sand grains. When the filter has become clogged the flow of water is reversed, filtered water being forced upward through the sand to wash it and to remove the impurities, which pass over the top of the filter with the wasted water. A revolving rake with long prongs projecting downward into the sand mixes it during washing and prevents it from becoming graded into spots of coarse or fine particles. In recently constructed works rectangular filters 300 to 1,300 square feet in area have been built, in which the sand is agitated during washing by compressed air forced through it at intervals instead of by a revolving rake. Larger orifices in the strainers are also being used, the passage of sand being prevented by fine gravel over the strainer pipes. The rate of filtration is from 100,000,000 to 120,000,000 gallons per acre per day. The time between washing is 6 to 12 hours, depending principally on the turbidity of the applied water.

Mechanical filtration removes practically all suspended matter, reduces the color to unobjectionable proportions, and under some conditions removes part of the dissolved iron. The permanent hardness of the water is increased in proportion to the amount of sulphate added by the coagulant, and if only enough lime to decompose the coagulant is added, the total hardness is slightly increased. If larger amounts of lime are added, however, the total hardness is reduced. If soda ash is used in place of lime the foaming constituents are slightly increased. The chemicals are always added in solution. As this method of filtration is used almost entirely for river waters with fluctuating contents of suspended and dissolved matter proper operation requires constant and intelligent attention.

COLD-WATER SOFTENING.

The principal objects of water softening are to remove the substances that cause incrustations in boilers, particularly calcium and magnesium, and to neutralize those that cause corrosion. Solutions of chemicals of known strength are added to the raw supply in such proportion as to precipitate all the dissolved constituents that can be economically removed by such treatment. The water is then allowed to stand long enough to permit the precipitate to settle, after which the clear effluent is drawn off; or the partly clarified effluent may be filtered very rapidly through thin beds of coke, sponge, excelsior, bagging, or similar material in order to remove particles that have not subsided in the tanks. The water softeners on the market differ from one another chiefly in the precipitant, in the filtering medium if one is used, and in the mechanism regulating the incorporation of the chemicals with the water. Installations may be of any size to suit consumption, and the process can

be combined with rapid sand filtration for purifying municipal supplies. Among the substances that have been proposed as precipitants are sodium carbonate (soda ash), silicate, hydrate (caustic), fluoride, and phosphate; barium carbonate, oxide, and hydrate; and calcium oxide (quicklime). Lime and soda ash, however, are almost exclusively used on account of their excellent action and comparative cheapness.

When soda ash (Na_2CO_3) and lime dissolved in water to form a solution of calcium hydrate, $Ca(OH)_2$, are added to a water in proper proportion free acids are neutralized, free carbon dioxide is removed, bicarbonate is decomposed, and iron, aluminum, and magnesium hydrates and calcium carbonate are precipitated. The precipitate in settling takes down with it a large proportion of the suspended matter. The treatment removes the incrusting constituents practically to the limit of their solubility, and also removes the calcium added as lime. Sodium, potassium, sulphate, and chloride are left in solution, and the alkalies are increased in proportion to the quantity of soda ash added; that is, the foaming constituents are increased, and the maximum proportion of these that is allowable in the treated water fixes the maximum proportion of incrustants that a raw water can contain and be satisfactorily treated. The proportion of incrustants left in a treated water is determined by the solubility of the precipitated substances and by the completeness of the reaction between the added chemicals and the dissolved matter. It has been brought below 90 parts per million in some well-treated waters. The sulphate radicle can be removed by using barium compounds, which precipitate barium sulphate, but the poisonous effect of even small amounts of barium and the relatively high cost of its salts are great objections to their use. The chlorides are not changed in amount by water softening. The chemicals should be very thoroughly mixed with the raw water and sufficient time should be allowed for complete reaction, which proceeds rather slowly, for otherwise precipitation will occur later in pipe lines or in boilers.

FEED-WATER HEATING.

Water heaters are designed primarily to utilize waste heat in stationary boiler plants by raising the temperature of the feed water and thereby lessening the work of the boilers themselves, but they also effect some purification, and many heaters have been specially designed with that end in view. The heat is derived from exhaust steam or from flue gases. Heaters utilizing steam either are open—that is, operated at atmospheric pressure—or are closed and operated at or near boiler pressure. In accordance with these different conditions, which result in distinct purifying effects, feed-water heaters

are classified as "open" or "closed" or "economizers," the last being those using flue gases. In most forms of open heaters, which are best adapted for removing large quantities of the materials that form soft scale, the steam enters at the bottom and the water at the top, and intimate contact between the two is obtained by spraying the water or by allowing it to trickle over or to splash against plates. By this process the water is quickly heated nearly to boiling; dissolved gases are expelled; bicarbonate is decomposed; and iron, aluminum, part of the magnesium, and calcium equivalent to the carbonate after decomposition of the bicarbonate are precipitated as hydrates, oxides, and carbonates under varying conditions of temperature, pressure, and time. The precipitate agglomerates the particles of suspended matter and makes them more readily removable by sedimentation and filtration. The slowness with which the reactions take place and the presence of acid radicles other than carbonate to hold the bases in solution prevent complete removal of calcium and magnesium. The addition of soda ash in proper proportion, however, effects fairly complete precipitation of the alkaline earths, and apparatus for constant introduction of this chemical in solution may be provided. Open heaters operated without a chemical precipitant remove constituents that are soft and bulky and leave those that form hard scale. Scale from water treated without chemicals in such heaters is therefore not so great in amount but is harder than that formed by the raw water. After the precipitate has been formed the water passes through filters of burlap, excelsior, straw, hay, wool, coke, or similar material, arranged in units that can readily be cleaned.

In closed heaters the water is passed through tubes surrounded by steam or around steam pipes, and manholes or other openings are provided for removing the scale from the tubes. As the water is heated under pressure some precipitation takes place, but closed heaters are not so efficient in this respect as open heaters, because they do not permit the escape of the gases liberated from the water. This objection does not hold if treatment in a closed heater follows treatment in an open one from which the gases escape. Several systems accomplish very good purification by using a unit of each type in series.

Economizers consist essentially of water tubes set in the flues leading from the furnaces. Facilities are provided for cleaning scale from the inside and soot from the outside of the tubes. As economizers are heated by flue gases, the water in the tubes can be heated under pressure to much higher temperature than in open or closed heaters, and conditions of ordinary boiler operation are approximated. The precipitation of incrustants varies greatly with the normally fluctuating temperature of the flue gases.

CHEMICAL COMPOSITION OF THE SURFACE WATERS.

RIVERS.

During a study of the quality of the surface waters of California conducted by the Geological Survey in cooperation with the California Department of Engineering in 1906–1908 samples of water collected daily for a period of one year at selected stations on several rivers in San Joaquin Valley were united in sets of 7 or 10 consecutive samples as deemed advisable, and analyses were then made of the composites thus obtained. As the complete analyses have already been published [1] it is sufficient here to quote only the mean, maximum, and minimum conditions of chemical composition during the progress of the investigation. The analyses prior to March, 1906, were made by F. M. Eaton; for the remainder of that year they were made by P. L. McCreary; and during 1908 by Walton Van Winkle, who was assisted by W J McGee, William Reinhart, and W. C. Packard.

[1] Van Winkle, Walton, and Eaton, F. M., The quality of the surface waters of California: U. S. Geol. Survey Water-Supply Paper 237, 1910.

TABLE 15.—*Quality of the river waters of San Joaquin Valley.*

[Parts per million except as otherwise designated.]

Source.	Condition.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total dissolved solids.	Total hardness as $CaCO_3$.[a]	Incrusting constituents.[a]	Foaming constituents.[a]	Alkali coefficient[a] (inches).
San Joaquin River near Lathrop, Jan. 1 to Dec. 31, 1906.	Maximum	264	19	0.10	41	16	68	0.0	123	60	92	358	169	167	184	20
	Minimum	4	10	....	8.9	3.6	11	.0	30	8.7	8.8	60	37	42	30	150
	Mean	60	16	.23	18	8.0	27	.0	66	26	30	161	78	82	73	65
San Joaquin River near Lathrop, Dec. 31, 1907, to Dec. 31, 1908.	Maximum	193	25	.20	40	21	77	.0	139	73	116	416	186	178	208	18
	Minimum	15	12	.45	6.6	3.1	6.1	.0	22	19	4.0	52	29	37	16	400
	Mean	52	19	.30	20	10	36	.0	74	39	47	205	90	95	97	40
Mokelumne River at Clements, Jan. 1 to Dec. 31, 1906.	Maximum	504	25	....	25	6.7	23	.0	84	24	19	126	91	110	62	90
	Minimum	28	11	....	6.3	1.8	9.0	.0	17	5.8	3.9	30	23	33	24	130
	Mean	84	14	.18	12	3.8	13	.0	42	12	7.3	75	46	56	35	120
Stanislaus River at Knights Ferry, Jan. 1 to July 31, 1906.	Maximum	642	9.6	....	23	7.4	15	.0	106	22	16	138	88	90	40	120
	Minimum	16	8.8	....	7.1	3.5	8.2	.0	25	9.2	4.9	44	32	36	22	320
	Mean	140	14	.20	11	5.0	11	.0	46	11	5.6	83	48	54	30	150
Tuolumne River at Lagrange, Jan. 1 to Dec. 31, 1906.	Maximum	284	11	.10	18	6.4	13	.0	72	17	7.1	134	71	75	35	200
	Minimum	12	6.0	....	3.7	2.0	9.3	.0	15	7.7	4.9	40	17	20	25	150
	Mean	68	11	.19	10	4.3	12	.0	41	12	6.6	74	43	48	32	140
Merced River at Merced Falls, Jan. 1 to July 31, 1906.	Maximum	260	24	....	21	5.6	15	.0	77	19	9.4	116	95	95	40	180
	Minimum	6	15	....	8.0	4.2	13	.0	17	7.3	3.9	40	37	46	35	80
	Mean	52	14	.10	9.1	3.8	9.3	.0	35	11	5.6	65	39	47	25	240
Kern River near Bakersfield, Jan. 1 to Dec. 12, 1906.	Maximum	1,836	22	....	39	6.1	108	.0	110	71	14	270	123	147	291	90
	Minimum	14	12	....	10	2.6	12	.0	30	9.4	4.4	56	36	46	32	100
	Mean	163	18	.15	18	4.2	22	.0	71	21	9.1	127	62	78	60	65

[a] Computed. Suspended matter has been disregarded in these computations in order that the results may be comparable with those calculated from analyses of ground waters.

The extremes of suspended and dissolved solids that are indicated in Table 15 did not necessarily occur at the same time, but the amounts of the various dissolved constituents correspond to the reported dissolved solids. The waters of Mokelumne, Stanislaus, Tuolumne, and Merced rivers, which were sampled at or near the entrance of the streams into the valley and before they have been used for irrigation, are low in all constituents, and they compare favorably with the waters of rivers along the Atlantic Coast, which are considered entirely acceptable in respect to their mineral constituents. The water of Hudson River at Hudson, N. Y., though less changeable in quality, is distinctly higher than any of these in dissolved matter, and the water of Lake Superior, carrying 60 parts per million of dissolved matter, is only slightly lower in mineral content. Though the California stream waters fluctuate considerably in their load of mineral matter, they are no more highly mineralized at their worst than the best of the ground waters. They would be classed as moderately soft by the most critical standards; they are low in dissolved scaling and foaming constituents, and therefore sedimentation to remove the varying amounts of suspended matter is all that is required to make them good boiler waters. The computed alkali coefficients indicate that the waters even at the lowest stages are excellent for use in irrigation, and this classification is amply corroborated by experience. Kern River, sampled at the mouth of the canyon 5 miles northeast of Bakersfield, is somewhat higher in mineral content than the other streams, but still it is moderate. Such increase in the southern end of the valley is natural in view of the low rainfall, which has been insufficient to remove from the ground the accumulation of soluble salts.

The analyses of water from San Joaquin River at the Southern Pacific Co.'s bridge near Lathrop, a few miles above Stockton (San Joaquin Bridge), show how evaporation, seepage from irrigated tracts, and surface and subsurface drainage from the entire valley increase the mineral content of the outflowing water and tend to differentiate it from the mountain tributaries. Yet, even though the river water is subject to these adverse influences, it is acceptable for irrigation and for boiler use. It varies greatly in quality from season to season, being lowest in dissolved matter during the spring freshets and highest during the fall when the river is at its lowest stages.

TABLE 16.—*Mean discharge of certain tributaries of San Joaquin River compared with the mean mineral content of that stream during 1906 and 1908.*

	1906	1908
Mean suspended matter in the water of San Joaquin River near Lathrop (parts per million)	60	52
Mean dissolved matter in the water of San Joaquin River near Lathrop (parts per million)	161	205
Mean discharge in second-feet per square mile: [a]		
Stanislaus River at Knights Ferry	3.63	.837
Tuolumne River at Lagrange	3.33	.960
Merced River at Merced Falls	2.63	.631

[a] U. S. Geol. Survey Water-Supply Papers 213 and 251.

The difference between the average quality of the water of San Joaquin River during different years is not very great, as the data in Table 16 indicate. The mean discharge of the three principal tributaries was approximately four times as great in 1906 as in 1908, but the amount of dissolved matter at San Joaquin Bridge was less than 30 per cent greater during the dry year, and the decrease of suspended matter corresponding to the decrease in discharge is only 13 per cent. In general suspended matter varies directly and dissolved matter inversely with the discharge of streams, but these relations are neither absolute nor invariable, and study of analyses of several other river waters has demonstrated that the fluctuation of the average content of mineral matter is not so great from year to year as the fluctuation in discharge.

TABLE 17.—*Comparison of the average condition of the water of San Joaquin River with the average condition of three tributaries in 1906.*

Constituents.	Parts per million.				Percentage of anhydrous residue.			
	Stanislaus River at Knights Ferry.	Tuolumne River at Lagrange.	Merced River at Merced Falls.	San Joaquin River near Lathrop.	Stanislaus River at Knights Ferry.	Tuolumne River at Lagrange.	Merced River at Merced Falls.	San Joaquin River near Lathrop.
Suspended matter	140	68	52	60	....	....	....	....
Dissolved solids	83	74	65	161	....	....	....	....
Total hardness [a]	48	43	39	78	....	....	....	....
Silica (SiO_2)	14	11	14	16	17.3	14.4	20.0	10.1
Iron (Fe)	.20	.19	.10	.23	.3	.2	.2	.1
Calcium (Ca)	11	10	9.1	18	13.6	13.1	13.0	11.4
Magnesium (Mg)	5.0	4.3	3.8	8.0	6.2	5.6	5.4	5.1
Sodium and potassium (Na+K)	11	12	9.3	27	13.6	15.8	13.3	17.1
Carbonate radicle (CO_3)	.0	.0	.0	.0	28.5	26.3	24.3	20.9
Bicarbonate radicle (HCO_3)	46	41	35	66	....	....	....	....
Sulphate radicle (SO_4)	11	12	11	26	13.6	15.8	15.8	16.4
Chlorine (Cl)	5.6	6.6	5.6	30	6.9	8.8	8.0	18.9

[a] Computed.

Comparison of the average condition of the San Joaquin for 1906 with the average condition of Stanislaus, Tuolumne, and Merced rivers, the three tributaries entering above San Joaquin Bridge, brings out the essential differences in the waters (Table 17). Though nearly all constituents are greater in quantity in the San Joaquin the principal change in chemical composition is increase of the percentages of sodium, potassium, and chlorine at the expense of carbonate; in other words, chlorides of the alkalies are added to the solution. The moderate increase in mineral constituents is less than what might be expected in view of the high mineral content of the west-side ground waters and the semiarid condition of the valley.

TULARE LAKE.

The usually high mineral content of the water as well as the intermittent nature of Tulare Lake prevents its use for irrigation. As the landlocked basin forms an immense evaporating pan in a semiarid region the dissolved salts that are brought in by tributary streams have been deposited in the lake bed after the water has evaporated, the salts being partly redissolved later or left under or mixed with protective layers of silt. That such successive concentrations, dilutions, and depositions have taken place for many centuries is shown by the known history of the lake and by the highly mineralized condition of the first few hundred feet of silt underlying its bed.

When the area of the lake has been greatest the proportion of substances in solution has been low enough to permit use of the water for irrigation, but its usual unfitness is established by analyses made by chemists at the agricultural experiment station of the University of California under the direction of E. W. Hilgard. The results of their tests, given in Table 18, can not be reduced to ionic form because of the methods of analysis and they are therefore given in the original hypothetical combinations, the only change being that the amounts have been converted from grains per gallon to parts per million.

TABLE 18.—*Partial analyses of water from Tulare Lake.*[a]

[Parts per million.]

	Total residue.	Residue insoluble in water.	Organic and volatile matter.	Sodium carbonate.	Sodium chloride, sodium sulphate, etc.
A	1,445	230	38	478	648
B	1,403	92	91	604	616
C	1,401	128	76	521	676
D	1,399				
E	1,400	143	39	478	740
F	3,504	63	241	1,272	
G	5,188	119	276	1,622	3,170
H	660	88	85	230	873
I	1,301	113	77	530	581

A. Near southeast corner of the lake inside of Root Island, 300 yards from shore.
B. Near middle of lake at surface.
C. Near middle of lake at depth of 10 feet.
D. Near middle of lake at depth of 20 feet. (The first four samples apparently were collected in the spring of 1880.)
E. Sample collected in January, 1880.
F. Sample collected in June, 1888.
G. Sample collected in February, 1889.
H. Near mouth of Kings River, March 28, 1880. Taken at surface when a strong wind brought in more river water than usual.
I. Near outlet of West Side Canal at depth of 10 feet. (Probably taken at same time as sample H.)

Samples A to E inclusive were collected in 1880 while the lake was decreasing in size and its dissolved salts were being concentrated. The samples collected at reasonable distance from the shore indicate that the lake throughout carried practically the same amounts of

[a] Compiled from California Univ. Agr. Exper. Sta., Rept. for 1890, appendix.

dissolved matter. The water at that time was too high in mineral content to be suitable for use. Samples F and G, taken in 1888 and 1889 while the lake was low, show much greater concentration of the soluble substances, the total residue having become more than tripled in 1889. The results of these tests prove the futility of any project involving use of the lake waters for irrigation. If the supply were suitable during uncertain periods when the lake is large the inevitable concentration accompanying evaporation would make the water dangerous during low stages. Dilution of such strong water by mixing it with a supply from Kings River would result in reducing one excellent water to poor condition.

TABLE 19.—*Chemical composition of the water of Tulare Lake.*[a]

Constituents.	Parts per million.			Percentage of anhydrous residue.		
	1	2	3	1	2	3
Total solids	1,400	1,401	5,188			
Organic and volatile matter	39	76	276			
Silica (SiO_2)	8	12	32	0.59	0.92	0.65
Alumina (Al_2O_3)		5			.38	
Calcium (Ca)	20	17	14	1.47	1.31	.28
Magnesium (Mg)	24	21	13	1.76	1.62	.26
Sodium (Na)	458	460	1,760	33.60	35.38	35.83
Potassium (K)	25		120	1.83		2.44
Carbonate radicle (CO_3)				26.56	28.62	19.52
Bicarbonate radicle (HCO_3)	735	755	1,945			
Sulphate radicle (SO_4)	230	203	1,020	16.87	15.61	20.76
Chlorine (Cl)	236	210	994	17.32	16.16	20.26
Scale-forming ingredients (s)	107	102	95			
Foaming ingredients (f)	1,300	1,240	5,100			
Probability of corrosion (c)[b]	N. C.	N. C.	N. C.			
Alkali coefficient (inches)	2.2	2.2	.6			
				100.00	100.00	100.00

[a] Analyses made in the chemical laboratory of the Agricultural Experiment Station, University of California.
[b] N. C.=noncorrosive.

Table 19, giving the chemical composition of the lake water in parts per million and in percentage of the anhydrous residue, shows in more detail the nature and amounts of the dissolved substances. Analysis No. 1, corresponding to E in Table 18, gives the composition in January, 1880; No. 2 is apparently the same as C (Table 18), collected in the spring of 1880; and No. 3 shows the composition in February, 1889. The analyses, stated by Hilgard in hypothetical combinations, have been computed to ionic form and to parts per million by the writer. The water belongs to the sodium carbonate type, the proportion of alkaline earths being low. The percentage of calcium and magnesium decreased greatly between 1880 and 1889, a change compensated by a proportionate increase in alkalies. The relative amount of carbonate decreased appreciably, while sulphate and chloride correspondingly increased. This indicates the deposition of alkaline-earth carbonates. The alkali coefficients are so low

that the water could not be considered suitable for irrigation. Though the amounts of scale-forming ingredients are low, and such waters would probably not corrode boilers, the contents of foaming constituents would render such supplies unfit for boiler service. Tulare Lake may be regarded as a catch basin whose water is valueless.

BUENA VISTA RESERVOIR.

Kern River has several delta channels spread fanlike in the valley west of Bakersfield, and some of these channels formerly conveyed the water of the river to a shallow depression comprising the basins of Kern and Buena Vista lakes and Buena Vista Swamp. In recent years, however, the original courses have been modified by levees and diversion canals until at present none of the flow reaches Kern Lake basin except intermittently through an irrigating ditch, and only the flow at high stages is directed toward Buena Vista reservoir. This body of water, occupying the former basin of Buena Vista Lake, in T. 31 S., R. 25 E., and T. 32 S., R. 25 E., is a storage reservoir for irrigation canals to the northwest. It is separated by a levee from the basin of Kern Lake, whose bed is now dry and under cultivation. The analysis of a sample from the east end of Buena Vista reservoir in the spring of 1896 is reported in Table 20.

TABLE 20.—*Partial analysis of water from Buena Vista reservoir.*[1]

[Parts per million.]

Total residue	503
Organic and volatile matter	100
Residue insoluble in water	111
Residue soluble in water	292
Soluble residue:	
Sodium sulphate	269
Sodium chloride	23
Sodium carbonate	0
Insoluble residue:	
Silica	53
Carbonates of calcium and magnesium and calcium sulphate	58

When the water is in the condition shown by these tests, or is more dilute, it is suitable for irrigation and for use in boilers. The water may be prevented from becoming too strong by continual replenishment from Kern River. Water from Kern Lake on March 24, 1880, before it dried up, contained more than 3,600 parts per million [2] of mineral matter and was bad for irrigation.

[1] Analysis performed in the laboratory of the California Agricultural Experiment Station under direction of E. H. Loughridge. California Univ. Agr. Exper. Sta. Rept. for 1895-1897, p. 77. Converted into parts per million by the writer.

[2] California Univ. Agr. Exper. Sta. Rept. for 1890, appendix, p. 48.

DENUDATION AND DEPOSITION.

RATE OF DENUDATION IN THE SIERRA.

San Joaquin Valley has been filled by alluvium deposited by entering streams, but how much of the deposition took place in an arm of the ocean, how much in a fresh-water lake, and how much above water, and many other circumstances of the fluvial upbuilding are more or less conjectural. The rate at which material in the active basin of San Joaquin River—the portion east of the present river bed and north of Kings River—is now being moved has been calculated from the analyses quoted in Table 15 and gagings of the tributaries, and the results of these calculations are summarized in Table 21. During 1906 approximately 225 tons per square mile in the form of dissolved matter and 265 tons per square mile in the form of suspended matter were transported from the slopes of the Sierra Nevada into the valley.

TABLE 21.—*Rate of denudation on part of the western slope of the Sierra Nevada in 1906.*

Drainage basin.	Area.[a]	Mean run-off.[a]	Mineral content of water.		Denudation.	
			Average suspended matter.[b]	Average dissolved matter.[b]	Suspended matter.	Dissolved matter.
	Sq. mi.	*Sec.-ft. per sq. mi.*	*Parts per million.*	*Parts per million.*	*Tons per sq. mi. per year.*	*Tons per sq. mi. per year.*
Mokelumne River above Clements	642	3.04	84	75	232	224
Stanislaus River above Knights Ferry	935	3.63	140	83	472	296
Tuolumne River above Lagrange	1,500	3.33	68	74	188	243
Merced River above Merced Falls	1,090	2.63	52	65	197	168
Weighted mean					265	225

[a] U. S. Geol. Survey Water-Supply Paper 213, 1907.
[b] U. S. Geol. Survey Water-Supply Paper 237, 1910.

The figures of denudation in tons of dissolved matter per square mile per year in Table 21 have been computed by multiplying together the mean run-off, the average dissolved matter, and the factor 0.985. Denudation as suspended matter can not be so well approximated by similar computation with averages because the amount of suspended matter carried during a heavy flood may be greater than that during all the rest of the year. Therefore, denudation as suspended matter has been computed for each 10-day period represented by the samples, and the sum of these estimates has been divided by the area of the basin to obtain the denudation in tons per square mile per year in the form of suspended matter. Thus the removal of material from 4,167 square miles of the Sierra has been estimated. If it is assumed that the denudation on the first three basins is typical of the north-

ern two-thirds of the mountain slope and that that on Merced River basin is typical of the southern third, the weighted means for the 7,500 square miles of the Sierra tributary to San Joaquin Valley north of Kings River may be obtained. These two figures represent an annual movement of 1,700,000 tons of dissolved matter and 2,000,000 tons of suspended matter into the valley. This is equivalent to a denudation of 26 ten-thousandths of an inch annually, or 1 inch in 385 years, a high rate of denudation.

These estimates do not take into account the dissolved matter that is carried into the valley by the ground waters, but as the present problem is essentially one of silt movement this chemically dissolved matter can be neglected. No allowance has been made for the "bottom load," or material rolled along the beds of the streams, because the meager information in reference to this manner of transportation tends to show that the bottom load moved past a given point in a river that is not overloaded is a very small percentage of the total load. The sectional area of the heavy load near the bottom is only a small part of the total cross section through which suspended matter is transported, and the bottom load necessarily moves more slowly than the lower filaments of water, which in turn move more slowly than any other waters in the cross section. Therefore, though bottom material may be obvious because of the size of its particles, it probably constitutes only a small fraction by weight of the total material that is moved.

How long a period may be represented by estimates based on one year's studies is uncertain. According to the figures representing the mean discharge of several streams in the valley,[1] the run-off during 1906 was considerably higher than normal, and the estimates of transported silt may, therefore, be considered greater than the normal for the present century.

RATE OF DEPOSITION IN THE VALLEY.

As no measurements of the discharge of San Joaquin River near Lathrop were made during the period in which samples were collected, 1.00 second-foot per square mile has been taken as a reasonable estimate of the average run-off throughout the 16,500 square miles of the basin north of Tulare Lake. This figure and the averages of analyses at Lathrop for 1906 (Table 17) give the annual removal of material by San Joaquin River as 2,600,000 tons of dissolved and 1,000,000 tons of suspended matter. That is, about 1,000,000 tons more of suspended matter and 900,000 tons less of dissolved matter are brought into the valley annually by the active east-side tributaries of the San Joaquin than are carried to the bay. The excess

[1] Clapp, W. B., The surface water supply of California: U. S. Geol. Survey Water-Supply Paper 213, 1907.

of dissolved matter undoubtedly is contributed by underflow. Though no perennial streams enter San Joaquin River from the west side above the sampling station at San Joaquin Bridge, some suspended and dissolved matter undoubtedly reaches the main stream over the surface during the rainy season. On the other hand, some of the suspended material brought into the valley by mountain streams is later disintegrated and dissolved and passes out in solution. These features slightly modify the estimates, some increasing and others decreasing the computed differences between outgoing and incoming material; due allowance for their influence, however, seems to be made by assuming that the difference between the amounts of outgoing and incoming silt represents the present annual accretion. This quantity, 1,000,000 tons, distributed evenly over the 3,500 square miles of plains region between San Joaquin River and the Sierra would represent an annual deposition of 285 tons per square mile. If this material, thoroughly dried and compacted by pressure, is assumed to weigh 100 pounds per cubic foot,[1] it would represent an annual upbuilding of 24 ten-thousandths of an inch, or 1 inch in about 420 years.

As wells in the valley have penetrated 2,000 to 2,500 feet of sediment, this annual accretion would indicate a period of not less than 6,000,000 years for the fluvial filling. It is, of course, absolutely a matter of speculation whether the present rate of deposition represents the average rate during the entire period in which the valley has been filled. Mr. Mendenhall states (p. 28) that "the wells drilled throughout the valley prove that the sediments underlying it are all fine," and this indicates that past rates of deposition could not have been much greater than the present rate, for if they had been the transported material would have been coarser and the particles of deeper sediments in the valley would now be larger than those of the upper sediments. But even under the extreme assumption that 4,000,000 tons, or twice the present amount, of silt had been brought annually into the valley and that none of it had been transported to the ocean, the time of filling would not be less than 1,500,000 years. This calculation, approximate and based on hypotheses though it may be, indicates that the time occupied by the valley filling involves geologic periods and not a few thousand years.

CHEMICAL COMPOSITION OF THE GROUND WATERS.

TYPES OF GROUND WATER.

The wells in San Joaquin Valley north of Tulare County yield three general types of water in relation to geographic position. The east-side and west-side types, named, as may be inferred, from their

[1] Dole, R. B., and Stabler, Herman, Denudation: In U. S. Geol. Survey Water-Supply Paper 234, p. 80, 1909.

position in the valley, are distinguishable from each other particularly by their difference in content of sulphate (SO_4), and the intermediate or axial type, occurring along the strip between the areas of typical east-side and west-side waters and blending into them, is distinguishable chiefly by its relatively high content of alkalies. As this geographic grouping greatly facilitates understanding of the general characteristics of the ground supplies and their usefulness discussion of it has been taken up in as much detail as the assays warrant. When the determinations of sulphate are plotted on a map, as in Plate II (in pocket), it is seen that nearly all the waters high in sulphate and no waters low in sulphate were found on the west side; and that very few waters on the east side north of Kern County contain more than 10 parts per million of sulphate. Waters high in sulphate are scattered over the east side of Kern County, but not enough tests were made to warrant definite conclusions regarding their distribution, and the following statements therefore relate particularly to conditions in the area north of that county.

CONDITIONS NORTH OF KINGS RIVER.

OCCURRENCE OF SULPHATE AND NONSULPHATE WATERS.

Water from wells less than 1,200 feet deep contains 80 to 2,000 parts per million of sulphate in the area west of the limit indicated by A′A′ in Plate II (in pocket). The quantity of the radicle is usually less in the northern part than in the broad plains south of Newman, where arid conditions of water supply are more nearly approached. A decrease from west to east in the quantity of sulphate is noticeable in most of the western area, but there are many exceptions to this relation, and it is not nearly so striking as the abrupt change that occurs between the limits indicated by lines A′A′ and C′C′ (Pl. II). Wells more than 200 feet deep east of the limit indicated by C′C′ yield water containing not more than 10 to 20 parts per million of sulphate and usually not more than 5 parts. Wells 200 to 1,000 feet deep were tested all over the eastern part of the valley; a well 2,500 feet deep at Stockton, one 1,800 feet deep at Corcoran, one 1,400 feet deep near Pixley, and a 1,300-foot well near Madera also were tested and none yields water carrying more than 10 parts of sulphate. It may be concluded, therefore, that this is a general condition applying to the entire eastern area north of Kern County. The water of wells less than 200 feet deep in the same territory north of Kings River contains practically no sulphate, but south of that river in Kings and Tulare counties high sulphate occurs in the water of shallow wells for a few miles east of the axis, and then abruptly disappear to recur in the water of only a few scattered wells between there and the foothills of the Sierra. The four waters that

were found to contain much sulphate far east of the axis in Tulare County are from wells in areas that have not been irrigated, and the ground around them shows accumulations of white alkali. The wells probably penetrate interdelta areas where alkali salts have been deposited by evaporation, and their waters might be improved by the leaching effect of irrigation accompanied by drainage. East of the boundary indicated by line B′B′ (Pl. II) sulphate does not occur in appreciable amount in the water of wells less than 200 feet deep except in the few scattered areas of Tulare County.

The boundary indicated by A′A′ parallels San Joaquin River and Kings River Slough, lying one-half to 6 miles west of them from San Joaquin Bridge to Tulare Lake. The boundary indicated by C′C′ runs in the same general direction, passing just west of Stockton, Modesto, Livingston, Lemoore, and Angiola. Boundary B′B′ lies between A′A′ and C′C′ from Stockton to Lemoore, where it crosses C′C′, diverging gradually from it and ultimately curving in a broad sweep eastward to the foothills. These boundaries do not show the exact limits of the areas of sulphate-bearing waters within 2 or 3 miles east or west, but in view of the large number of tests it is fairly certain that wells 1,200 feet or less in depth west of boundary A′A′ yield sulphate waters and that wells less than 1,200 feet and probably those 2,000 or more feet deep east of boundary C′C′ yield nonsulphate waters. Between these two boundaries, which separate the areas of typical east-side and west-side waters, lies a strip 3 to 15 miles wide in the axis of the valley, where the change in sulphate content occurs. North of Kings River the change in the water from wells of the same depth along parallels is abrupt, and the farther the wells are from the west side of this strip in the axis the deeper they can be bored without striking sulphate water.

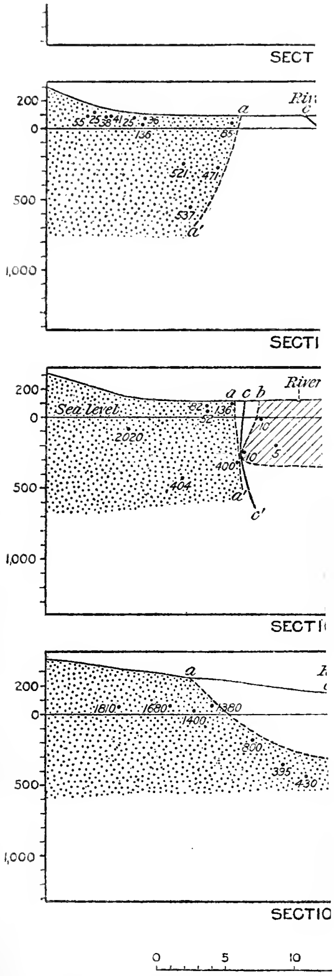
CAUSE OF THE DIFFERENCE IN COMPOSITION OF WATER.

This essential difference in the chemical composition of the ground waters is traceable to the structure of the plain. Geologically San Joaquin Valley is a deep trough that has been filled to its present level by material washed down from the slopes of the mountains bounding it, and the chemical characteristics of the filling material are essentially those of the rocks from which the material has been derived. The rocks of the Sierra are principally granites and metamorphic igneous slates and schists. These hard, difficultly soluble rocks and the sedimentary rocks derived from them that lie along the eastern foothills as far south as Madera County and also in Kern County have supplied to the valley material that is in turn capable of yielding little mineral matter to water percolating through it; consequently the areas of east-side débris furnish ground waters

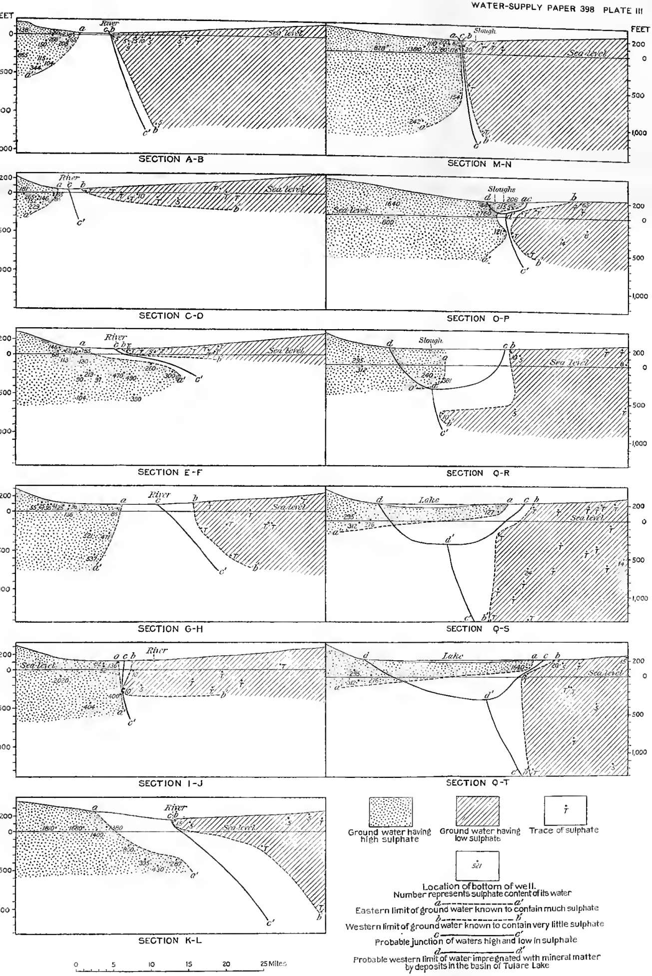
notably low in all mineral constituents. On the other hand, the rocks of the Coast Range, consisting largely of Cretaceous shales and sandstones and the calcareous gypsiferous shales, sandstones, and clays derived from them are much more soluble, and the filling material of the west side of the valley is therefore distinctly different from that of the east side. The water that passes through the west-side alluvium becomes highly impregnated with mineral matter and constitutes a distinct type of supply whose essential characteristic is the presence of large quantities of sulphate and correspondingly large quantities of bases.

CONTACT ZONE OF SULPHATE AND NONSULPHATE WATERS.

In order to trace more closely the boundaries of these characteristic types of water cross sections have been plotted along the east and west lines indicated in Plate II (see cross sections AB to MN, inclusive, Pl. III). The numbers on the cross sections represent the amounts of sulphate found in the ground waters. The position of the dot near each number in reference to the surface profile corresponds to the depth of the well, and its position in reference to the vertical axis corresponds to the distance of the well from the west side of the valley, all the cross sections originating at the foothills of the Coast Range. Dotted lines aa′ indicate the known eastern boundaries of zones of sulphate water and dotted lines bb′ the known western boundaries of zones of water very low in sulphate. The width of the uncertain strip between aa′ and bb′ obviously differs in the several sections according to the available information regarding quality. Solid lines cc′ indicate in each section the probable junction between the zones of sulphate and nonsulphate water, and the degree of uncertainty of its location is clearly indicated by its relation to the other lines. The upper end of boundary cc′ is located on the west side of the present beds of the axial watercourses in all the sections except IJ and MN, though the uncertain strip is 2 to 10 miles wide at the surface except in section MN. This apparently empirical location of the boundary is explainable by the fact that local information indicates the sulphate or nonsulphate character of the water near the surface in many places where tests could not be made. No analyses of water along the location of section AB are available on the west side nearer the river than Banta, but the poor quality of two waters less than 2 miles west of the river was evident from their taste. In section CD, aa′ is very near the location of the river, and east of Newman and Los Banos and at Mendota (sections EF, GH, and KL) shallow borings, when they contain water, are currently reported to yield highly mineralized supplies. Therefore it is probable that cc′ should have about the surface location indicated. The abrupt change in character of the waters is not absolutely demonstrated for



CROSS SECTIONS SHOWIN



CROSS SECTIONS SHOWING SULPHATE CONTENT OF GROUND WATERS IN SAN JOAQUIN VALLEY.

the entire distance from San Joaquin Bridge to Kings River, but that the transition is effected very quickly in some regions is shown by the data in sections IJ and MN, in which the sulphate content of the ground waters drops from 100 to 500 parts per million down to practically nothing within 2 or 3 miles.

In all the sections cc′ dips eastward; that position is clearly established in sections EF, KL, and MN, and comparison of data for wells near the other sections but not included in them shows the probability of a generally similar dip everywhere between San Joaquin Bridge and Kings River. The dip of cc′ explains why some shallow wells near the axis yield better water than deep ones. For example, wells of any depth less than 600 feet in Newman (see section EF, Pl. III) yield water high in sulphate; in Stevinson Colony, a few miles farther east, however, water from wells less than 80 feet deep contains almost no sulphate, but water from wells exceeding 250 feet in depth is as high in sulphate as that in Newman, and a well in Livingston or east of that city could probably be drilled to any depth without striking sulphate water.

RELATION BETWEEN THE CHARACTER OF THE WATERS AND THE ORIGIN OF THE SILTS.

What relation the boundary between these types of water bears to the junction of the east and west encroachments of silt deposited during the filling of the valley is a geologic problem that need not be extensively considered. It is significant that the present bed of the river, the lowest part of the land surface, coincides so nearly with the surface boundary between the types of ground water. As silts that are now transported to the axis from both sides of the valley are sharply divided from each other by being diverted to a northerly course at the river ground waters moving toward the axis—at least those near the surface—would be differentiated in chemical composition because the sediments through which they are passing are derived from rocks of different character. Such waters can not mingle to any great extent both because of their being balanced by hydrostatic pressure and because of their diversion underground to follow the northerly course of the river. Consequently it is reasonable to conclude that the bed of the river always has been the junction line of the two apposed influxes of débris and that the line of demarcation between the types of water represents successive positions of the river channel during the upbuilding of the valley. Such supposition readily explains the comparatively sharp change in the character of the waters, a condition that would not exist if the east-side waters had pushed westward into the west-side sediments or if the west-side waters had entered the east-side sediments. The westward migration of the bed of the

stream is caused by the greater proportion of silt contributed by the east-side streams because of their greater discharge and the more rapid upheaval of the Sierra.

The only well on the west side found to contain very little sulphate is 2,250 feet deep and in sec. 14, T. 18 S., R. 18 E., midway between the locations of cross sections MN and OP and about 3 miles west of Kings River Slough. This apparent lack of sulphate in the waters of the deep sediments on the west side indicates the presence of sediments like those of the east side below the typical material of the west side, but as no other well approaching this one in depth could be found, this single test does not furnish sufficient evidence for definite conclusions.

CONDITIONS AROUND TULARE LAKE.

CONTACT ZONE OF SULPHATE AND NONSULPHATE WATERS.

The relations between the east-side and west-side types of ground water change materially near the outlet of Kings River. Shallow wells bordering the north and east shores of Tulare Lake yield water high in sulphate and other constituents, but deep wells in the same area yield water exceptionally low in all constituents, including sulphate. The reason for this apparently confused condition can be made clear by consideration of the cross sections depicted in Plate III and figure 3. The section indicated by OP (Pl. III) starts at the foot of the hills west of Huron, crosses Kings River Slough southwest of Lemoore, and passes through Hanford. The sections indicated by QR, QS, and QT have their origin at a common point in T. 21 S., R. 18 E., and radiate across the basin of Tulare Lake, passing, respectively, south of Stratford, through Tulare, and north of Angiola. Lines aa′, bb′, and cc′ represent, respectively, the known eastern boundary of sulphate water, the known western boundary of nonsulphate water, and the probable contact between those two types of water.

The relations between aa′, bb′, and cc′ in sections OP–QT indicate that the overlapping of the zone of sulphate-bearing waters is due to saline material that has been deposited in the lake bed during successive evaporations of the lake water. Kern, Kaweah, and other rivers now regularly or intermittently tributary to Tulare Lake formerly discharged their waters north toward San Joaquin River, but the outpushing delta of Kings River, gradually cutting off the higher end of the valley, formed the basin of Tulare Lake and altered the river courses. Shallow Tulare Lake, which fluctuates greatly in area, has been completely dry within recent years, and undoubtedly similar periods of low water and dryness have been often included in the history of the lake since its formation. After the water has

been removed by evaporation the mineral substances thus left behind have strongly impregnated the bed with salts, which later influxes of silt have partly covered and protected from resolution. Thus as the valley has been built up the lake basin has been filled with alter-

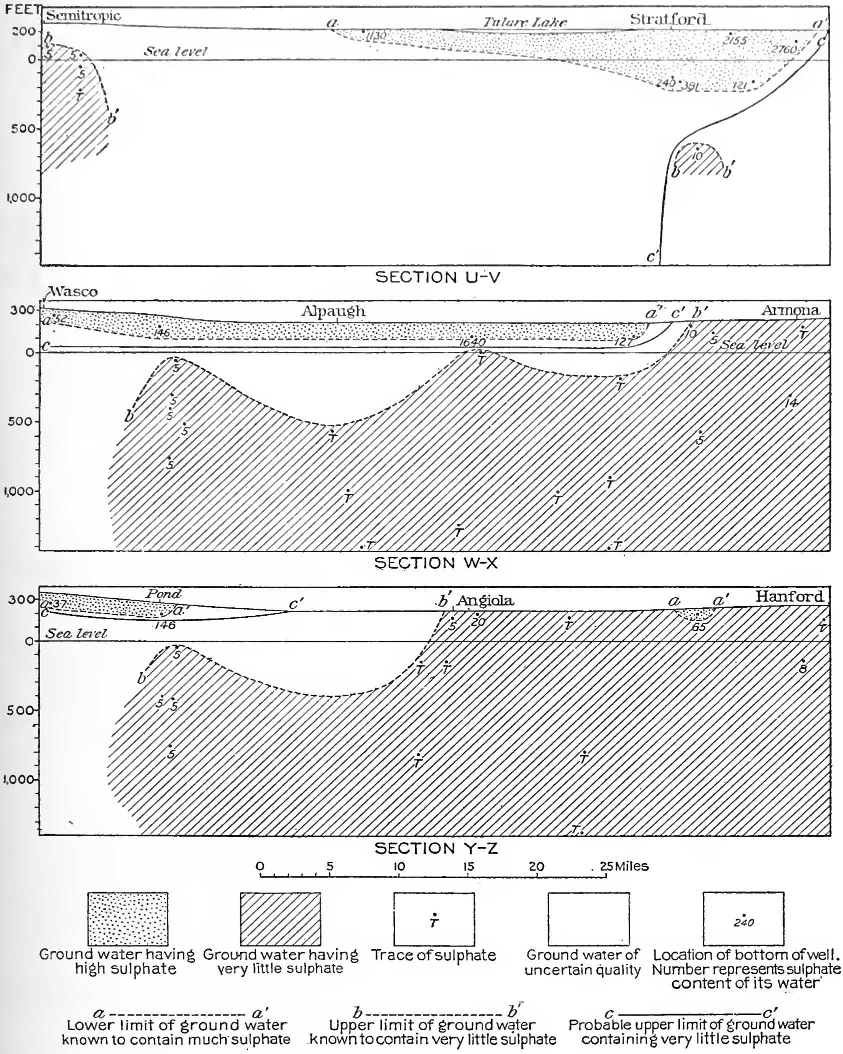


FIGURE 2.—Longitudinal sections showing sulphate content of ground water in the vicinity of Tulare Lake.

nating or mixed layers of silt and saline deposits that now yield highly mineralized waters to wells entering them. Wells that pass completely through the old lake beds on the east side reach sediments capable of furnishing excellent supplies because they are unmixed with the saline deposits. Therefore aa′ in sections OP–QT marks

not only the known east boundary of the zone of sulphate water, but also the known boundary of the zone of saline impregnation, while cc′ shows the probable boundary between the east-side and west-side types of water for part of its length and the boundary between the east-side and the superimposed "lake residue" waters for the remainder. The correct position of dd′, indicating the probable western boundary of the lake deposits, is highly uncertain, but the eastern boundary of the zone affected by the lake residues is fairly well fixed by the results of tests of water from shallow wells. It runs southeast from Lemoore (see B′B′, Pl. II) to Corcoran, thence to Angiola, beyond which its location is not well defined. One well 40 feet deep east of B′B′ in sec. 1, T. 19 S., R. 21 E., yields water containing 65 parts per million of sulphate, but this doubtless enters a small isolated tract of alkali.

The distribution of sulphate in the waters under the basin of the take is portrayed also by longitudinal sections UV to YZ in figure 2, the locations of which are indicated in Plate II. The known boundaries of zones of sulphate and nonsulphate waters are indicated by aa′ and bb′ as in Plate III except that in the longitudinal sections the boundaries mark north and south instead of east and west limits. The "uncertain area" in the section across the east side of the present lake from Semitropic to Stratford (section UV) is necessarily extensive because so few ground waters were available for examination. In the same section cc′ indicates the probable contact of sulphate and nonsulphate waters at the north end of the lake, but no similar boundary can be located at the south end, for the only water that could be tested between the lake and Semitropic was taken from a 20-foot dug well and contained 1,130 parts per million of sulphate. More abundant data in section WX, 8 miles east of and parallel to UV, permit location of the contact (cc′) with fair degree of probability at an average depth of 170 feet. In the section represented by YZ, 3 miles east of and parallel to WX, the influence of the lacustrine deposits does not appear. The sulphate water in one well near Hanford probably comes from a small spot of alkali. The shallow wells in the southern part of this section are affected by the sediments of different character in Kern County.

TOTAL MINERAL CONTENT OF WATERS.

Additional evidence that the highly mineralized condition of the aquifers under the lake is caused by saline residues is afforded by the results of other tests besides those for sulphate. All excessive amounts of chloride and bicarbonate in ground waters near the lake were found either west of or almost exactly in the position indicated by bb′ (Pl. III), a fact indicating that bb′ represents the eastern limit of the zone of highly mineralized waters and also indicating concen-

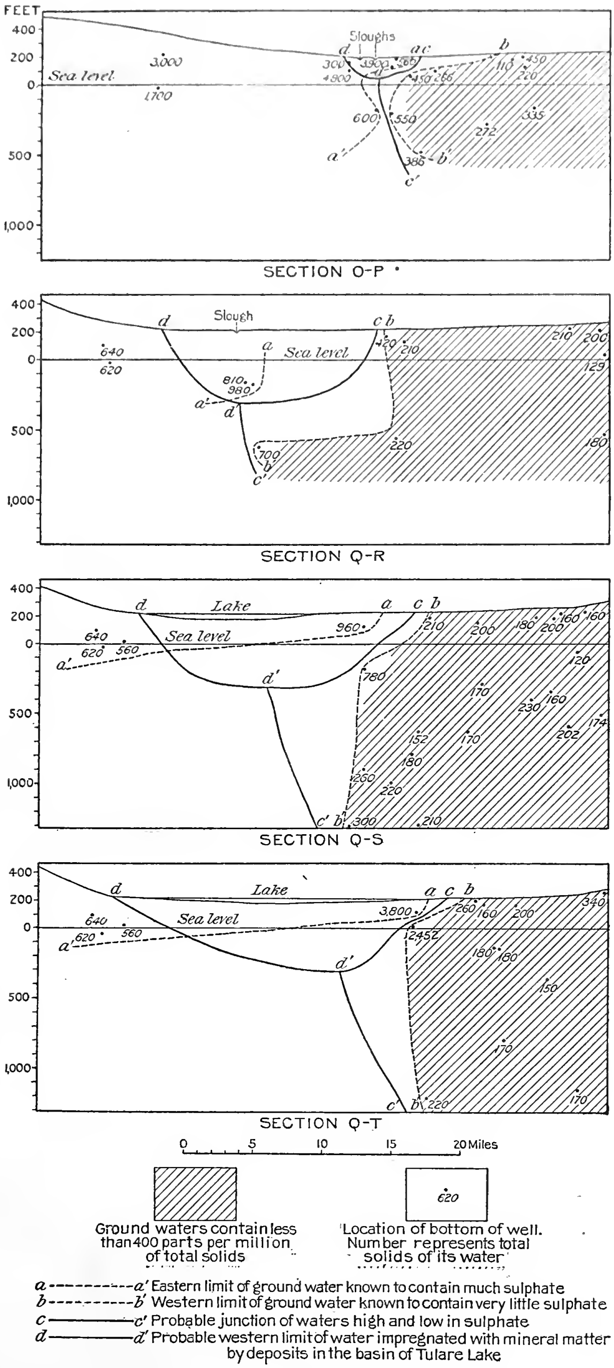


Figure 3.—Cross sections showing mineral content of ground water in the vicinity of Tulare Lake.

tration and deposition from highly saline solutions as the causes of the impregnation of the shallow waters with mineral matter.

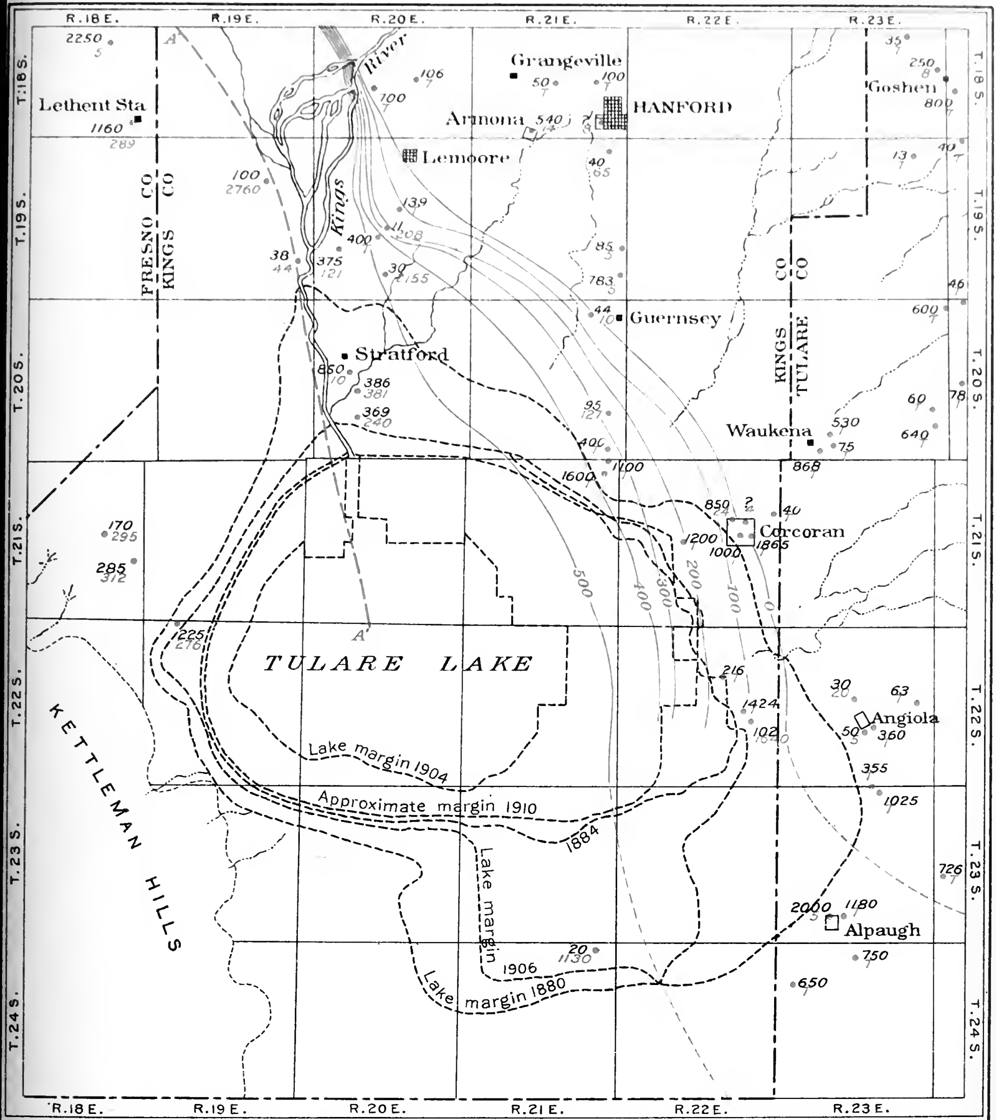
The relation of the total mineral content of the waters to the probable boundaries of the old lake basin is graphically summarized in figure 3. The boundaries aa′, bb′, cc′, and dd′ in these four sections are those shown in Plate III, but the figures give the calculated total mineral content of the waters. All waters from the alluvium above the boundary indicated by dd′c are high in mineral content and waters from wells west of the lake are, of course, also high for the west side is normally a region of high mineral content. The bottoms of five wells yielding water containing more than 400 parts of total solids are in the boundary indicated by bb′ (fig. 3), but no well whose water exceeded that amount was found in the eastern part of the area.

THICKNESS OF THE LACUSTRINE DEPOSITS.

The maximum thickness of the lacustrine deposits is not entirely established because of the limited range of depth of wells that could be tested and because of uncertainty whether the high mineral content of wells near the middle of the basin is due to mineralization by typical west-side alluvium or by lake deposits. Along boundary B′B′ (Pl. II) the thickness is not more than 8 or 10 feet. Southwest of Lemoore the water of a well 375 feet deep (section OP, Pl. III) contains 121 parts of sulphate, and the water of a well 386 feet deep near Stratford (section QR, Pl. III) contains 381 parts of sulphate, but that of an 850-foot well as near the slough and 3 miles farther north yields water containing only 10 parts per million of sulphate. The water of a 95-foot well (section QS, Pl. III) in sec. 25, T. 20 S., R. 21 E., contains 127 parts of sulphate, and that of a 400-foot well near by practically none; the water of a 102-foot well in sec. 23, T. 22 S., R. 22 E. (section QT, Pl. III), contains 1,640 parts, and that of a 216-foot well in the next section practically none. It may be concluded that the maximum thickness of the lacustrine deposits is certainly not less than 100 feet nor greater than 850 feet and probably about 400 feet and that the thickness is much less near the edges of the basin. Boundaries cc′ and dd′ have been located in sections OP to QT inclusive (Pl. III) in accordance with these conclusions.

PROPER DEPTH OF WELLS NEAR TULARE LAKE.

Plate IV shows the depths to which wells near Tulare Lake should be sunk in order to strike water of good quality. The purple contour lines, indicating the depth in feet below which waters containing sulphate or excessive amounts of other mineral constituents will probably not be encountered, have been located in accordance



MAP OF TULARE LAKE AND VICINITY, CALIFORNIA
Showing depth to which sulphate water may be obtained
and location of wells from which water was tested

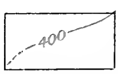
5 0 5 10 Miles

1915

LEGEND

Location of well from which water was tested. Black number indicates depth in feet; purple number indicates sulphate content of water in parts per million. T signifies trace of sulphate

Line west of which ground waters contain large amounts of sulphate (*Reproduced from Plate II*)



Contours indicating depth in feet below which sulphate waters will probably not be encountered (*Wells should be bored 50 to 100 feet deeper to assure good water*)

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with the data in sections OP to YZ, inclusive of Plate III and figures 2 and 3. Dependence has necessarily been placed in the reported depths of wells. Boundary A′A′ corresponds to boundary A′A′ indicated in Plate II.

For safety wells should be sunk 50 to 100 feet deeper than the depths indicated by the contours, and as practically all the water in the upper strata is highly impregnated with mineral matter the casings should be tight down to the good water. Though it is not known how far west of the location of the 500-foot contour wells can be drilled without encountering sulphate water, line A′A′ represents the extreme western limit of nonsulphate water at all depths, and the safe limit even for deep wells is probably not beyond the middle of the lake, the shore of which in 1910 is shown by a dotted line located from personal observation and local report without instrumental data. Within the area near Tulare Lake designated as yielding nonsulphate water spots may be found where supplies of poor quality may be afforded by deep wells, but such spots will be small. Information regarding the quality of ground waters immediately south of Alpaugh is scanty.

CONDITIONS SOUTH OF TULARE LAKE.

Data on the quality of ground water in Kern County are restricted to so few areas that conclusions can be formed only in respect to local characteristics, the analyses being discussed in more detail on pages 292–294. The water of wells 200 to 1,000 feet deep at Pond, Semitropic, Buttonwillow, and Oil Center contains little sulphate, but the deep water in the basin of Kern Lake contains some, and nearly all ground water southeast of Bakersfield to a depth of at least 300 feet seems to contain much sulphate. A well 686 feet deep 6 miles west of Buttonwillow, whose water carries 49 parts per million of sulphate, may mark the eastern boundary of the west-side type of water. Contrary to conditions farther north, many shallow waters in the east part of the valley in Kern County are rather high in sulphate and other substances. This high mineral content may be due to the influence of the Pliocene and Miocene sediments at the base of the Sierra, which in Kern County are different in texture and composition from those north of Madera County.

Cretaceous rocks are plentiful and the ground waters are notoriously bad in the foothills south of the basin of Kern Lake. Therefore, the high sulphate content of ground water in the adjacent portions of the valley is probably caused by the character of the silt washed down from the hills as well as by concentration similar to that which has occurred in the basin of Tulare Lake. The data

in section D′E′ (fig. 4) indicates a gradual increase of mineral content of the ground water from north to south across the basin of Kern Lake, the bed of which is now dry and under cultivation. The deep waters under the lake bed contain measurable quantities of sulphate, but none is particularly high in dissolved solids, and all are greatly superior to the shallow waters around Tulare Lake. This more favorable condition is explained by the fact that the Kern basin has not been landlocked so long as that of Tulare Lake.

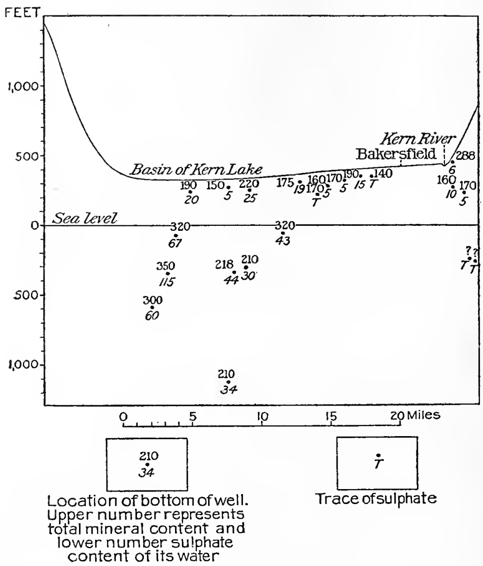


FIGURE 4.—Section D′E′, showing content of sulphate and total mineral matter of ground waters in the basin of Kern Lake.

COMPOSITION AND QUALITY OF EAST-SIDE WATERS.

Ground waters distinctly of the east-side type occur east of the boundaries indicated by B′B′ and C′C′ in Plate II (in pocket), and the location and significance of these boundaries have been discussed (pp. 100–104). Wells less than 1,100 feet deep in the east side north of Kern County yield waters much alike in total mineral content and in composition. These waters are the best ground supplies in the valley, being usually acceptable for all purposes and belonging almost exclusively to the calcium carbonate class [1] typical of humid and semihumid regions. On the east side near the axis sodium carbonate and some sodium chloride waters are found, but sulphate waters are found only in a few widely separated tracts in Tulare County. The averages in Table 22 show the characteristics of the east-side waters and their similarity to each other.

[1] For the explanation of this and similar terms defining the character of water see p. 80.

TABLE 22.—*Average chemical composition and quality of water from wells 20 to 1,100 feet deep east of the boundaries indicated by B′B′ and C′C′ in Plate II.*

[Parts per million except as otherwise designated.]

	San Joaquin County.	Stanislaus County.	Merced County.	Madera County.	Fresno County.	Tulare County.	Average.	Limits of individual determinations.	
								Highest.	Lowest.
Number of analyses	40	21	26	20	34	67	[a] 208	....	....
Carbonate radicle (CO_3)	0	0	0	0	0	Tr.	0	18	0
Bicarbonate radicle (HCO_3)	160	160	140	125	135	140	140	344	35
Sulphate radicle (SO_4)	5	Tr.	Tr.	4	4	8	4	202	Tr.
Chlorine (Cl)	35	50	25	40	20	35	35	490	4
Sodium and potassium (Na+K)	35	35	30	20	30	40	30	500	4
Total hardness as $CaCO_3$	140	140	100	120	70	100	110	500	4
Total solids	280	310	210	220	210	240	240	1,500	50
Alkali coefficient (k) (inches)	50	60	60	60	70	40	60	400	4
Scale-forming constituents (s)	180	190	140	160	130	140	160	460	40
Foaming constituents (f)	100	90	80	60	80	110	90	1,000	0

[a] Total.

The averages, which have been computed from the results of the assays, are arranged in geographic order from north to south, and they are graphically represented in Plate V (p. 120). Tests were made for carbonate, bicarbonate, sulphate, chloride, and total hardness, and the other quantities are computed from the results of those tests. The mean of 208 analyses represents a water moderate in total solids, fairly hard, and without distinct taste due to mineral matter, and therefore unobjectionable from a chemical standpoint for domestic use; such water would be fair for boiler use, as it contains only a moderate amount of scale-forming matter and little foaming matter; and it would be entirely acceptable for irrigation. The averages by counties represent waters of the same type, for the differences in some of the constituents are not great enough to have particular significance. The apparent tendency toward decrease southward in hardness and bicarbonate may be explained by the decrease in rainfall, which results in a decrease in the quantity of carbon dioxide supplied by decaying vegetation. The last two columns of Table 22 show that local fluctuations in quality are far greater than the differences in the county averages, and they indicate that there is considerable latitude for selection when supplies of lowest mineral content are necessary. The fluctuations are much greater in Tulare County than in any other part of the region. Altogether the waters of wells less than 1,100 feet deep are more nearly uniform in quality throughout the east side than in any other part of the valley.

TABLE 23.—*Chemical composition of water from wells more than 1,100 feet deep east of the boundaries indicated by B′B′ and C′C′ in Plate II.*

[Parts per million except as otherwise designated.]

	San Joaquin County.	Madera County.	Fresno County.	Tulare County.
Carbonate radicle (CO_3)	0	0	Tr.	18
Bicarbonate radicle (HCO_3)	110	137	417	68
Sulphate radicle (SO_4)	5	Tr.	Tr.	5
Chlorine (Cl)	2,900	1,160	135	15
Sodium and potassium (Na+K) [a]	1,300	485	240	50
Total hardness as $CaCO_3$	1,650	776	47	8
Total solids [a]	5,900	2,000	610	170
Depth of wells (feet)	1,200 to 2,500	1,310	1,200	1,400

[a] Computed.

East-side wells more than 1,100 feet deep yield water entirely different in composition from that of shallower wells. Four wells, 1,200 to 2,500 feet deep, in San Joaquin County yield salt water unfit for use. (See Table 23.) The 1,310-foot well near Madera supplies salt water much lower in mineral content than that from the deep wells in San Joaquin County. The 1,200-foot well east of Wheatville, Fresno County, yields water much lower in chloride and all other constituents, but carbonate is so high that the water is poor for irrigation. The supply of the 1,400-foot well in T. 22 S., R. 24 E., represents conditions in Tulare County, where some of the best waters are struck at depths greater than 1,100 feet. This sodium carbonate water is low in mineral content and fairly acceptable for boiler supply and for irrigation. It is important to note that neither this well nor those as deep as 2,000 feet near Tulare Lake encounter salt water, as do wells of similar depth near Stockton.

COMPOSITION AND QUALITY OF WEST-SIDE WATERS.

GENERAL CHARACTER.

Typical west-side ground waters occur west of the boundary indicated by A′A′ in Plate II (in pocket). They are not so uniform in mineral content as the waters of the east side, but they are much higher in mineral content, and they are characterized by high percentages of sulphate. Calcium sulphate or gypsum waters occur generally near the foothills of the Coast Range, and sodium sulphate waters near the axis of the valley. The west-side supplies as a class are so highly mineralized that they are very hard and are unsuitable for boiler use without purification. Nearly all of them have a distinct "alkali" taste and many are unpalatable. Fortunately, however, the sulphate nature of the dissolved matter makes it relatively less harmful to crops, and comparatively few supplies are absolutely unfit for irrigating lands.

QUALITY IN RELATION TO GEOGRAPHIC POSITION.

The quality of the west-side ground waters differs so much from place to place that no more definite description of the waters as a class can be given than that in the preceding paragraph. The region has, therefore, been roughly divided into districts, in which the supplies are more or less comparable with each other, for, unlike the waters of the east side, the waters of the west side are dependent in quality more on geographic position than on depth. The averages of analyses of water in each district, presented in Table 24, indicate approximately the character of the west-side supplies and the differences to which they are subject. The last column, giving the average quality of ground waters on the east side of the valley, has been added for comparison. The total mineral content of water in each district is graphically represented in Plate V (p. 120).

TABLE 24.—*Average chemical composition and quality of ground waters west of the boundary indicated by A′A′ in Plate II.*

[Parts per million except as otherwise designated.]

	San Joaquin County near foothills.	San Joaquin County between Tracy and San Joaquin River.	Stanislaus County.	Merced County northwest of Los Banos.	Merced County southeast of Los Banos.
Number of analyses	5	15	21	14	9
Carbonate radicle (CO_3)	Tr.	Tr.	Tr.	Tr.	Tr.
Bicarbonate radicle (HCO_3)	180	190	220	240	180
Sulphate radicle (SO_4)	690	200	220	70	330
Chlorine (Cl)	300	75	300	60	440
Sodium and potassium (Na+K) [a]	340	50	130	50	360
Total hardness as $CaCO_3$	620	280	400	250	380
Total solids [a]	1,800	640	930	510	1,530
Alkali coefficient (k) (inches) [a]	4	30	21	40	6
Scale-forming constituents (s) [a]	650	310	420	300	410
Foaming constituents (f) [a]	900	230	340	150	960

	Fresno County northwest of Mendota.	Fresno County near foothills south of Mendota.	Fresno County near slough south of Mendota.	Kings County.	Average quality of east-side waters.
Number of analyses	7	7	10	3	208
Carbonate radicle (CO_3)	Tr.	0	0	Tr.	0
Bicarbonate radicle (HCO_3)	150	145	250	70	140
Sulphate radicle (SO_4)	1,140	1,160	420	290	4
Chlorine (Cl)	220	130	70	50	35
Sodium and potassium (Na+K) [a]	350	240	240	110	30
Total hardness as $CaCO_3$	900	1,040	250	170	110
Total solids [a]	2,300	2,100	1,030	610	240
Alkali coefficient (k) (inches) [a]	9	12	20	25	60
Scale-forming constituents (s) [a]	950	840	280	240	160
Foaming constituents (f) [a]	900	640	660	310	90

[a] Computed.

The waters of five wells, 46 to 268 feet deep, in San Joaquin County between Tracy and the western foothills belong to the sodium sulphate class, and they carry 900 to 2,500 parts per million of min-

eral matter, 250 to 960 parts of which is sulphate. They are poor for irrigation and too high in scale-forming and foaming constituents to be fit for boiler use.

Alkalies predominate in some of the 15 waters from widely scattered wells 20 to 400 feet deep in the same county south and east of Tracy and west of San Joaquin River, but most of the waters belong to the calcium sulphate class. All would be considered poor for boilers because they would form large quantities of hard scale and would cause foaming. They are better than the waters near the foothills, however, and they are low enough in mineral matter to be suitable for irrigation. Depth bears no apparent relation to quality, except that in certain sections the shallow supplies are somewhat worse than the deep ones.

The part of Stanislaus County between San Joaquin River and the western foothills is narrower than the rest of the west side, and consequently the normal ground water there is affected by mixture with the more highly mineralized water that is slowly percolating northward from farther south in the valley. The 21 supplies that were tested in western Stanislaus County differ greatly from each other in composition, ranging from the calcium sulphate to the sodium chloride type. The artesian waters near San Joaquin River, like those in Stevinson colony across the river, are salty, rather poor for irrigation, and capable of foaming in boilers. Wells 20 to 200 feet deep throughout the region yield supplies containing chlorine in amounts ranging from 15 to 300 parts without apparent regularity. Most of the waters could be used for irrigation, but none is good for boiler use because of the high content of scale-forming and other ingredients.

Conditions in Merced County are similarly complex and irregular. West and north of and including Los Banos 14 wells, 23 to 580 feet deep, yield better water than wells southeast of that city. Sulphate is lower than in other parts of the west side and chloride likewise is moderate, but both radicles are always present in appreciable amount. The waters generally can be used for irrigation without causing trouble by their mineral content, but they need to be softened before being used in boilers. Waters from different depths show irregular local differences of quality.

The ground supplies southeast of Los Banos are poorer than those northwest of that city, and resemble those of northwestern Fresno County. They are strong sodium sulphate and sodium chloride waters that range from fair to very poor for irrigation. Their contents of foaming and scale-forming ingredients are so great that they are poor for boiler use, and some of them are industrially useless. A few shallow wells near irrigation ditches yield water better than the average.

The broad flat west side of Fresno County, at present occupied by sheep ranches and a few isolated farms, did not afford much opportunity for investigation, but the results of the tests that could be made make it apparent that this region yields the hardest and most strongly mineralized ground waters in the west side of San Joaquin Valley. Most of the wells near San Joaquin River and Kings River Slough yield sodium sulphate waters lower in mineral content than those farther west. Ten waters from wells thus situated and 20 to 1,100 feet deep contained 600 to 1,700 parts per million of total solids. All would be likely to foam in boilers and could be distinctly improved by being purified before use. Most of them could be applied in irrigation under proper conditions of drainage to prevent alkali accumulation.

The waters farther west in Fresno County are very high in sulphate and alkaline earths; that is, they are gypsum waters. Though this makes their content of incrustants so high that they are very bad for boiler use, it does not influence to so great extent their value for irrigation, and many of them could irrigate crops if proper precautions for drainage were taken. Few shallow wells on the plains yield water, wells usually being 100 to 700 feet deep, and it is improbable that any better water would be encountered by boring deeper. A well 2,250 feet deep yields sodium chloride water high in carbonate and very poor for irrigation or for boilers. The great quantity of gas in it makes it likewise unpalatable.

Three wells, 170 to 285 feet deep, west of Tulare Lake, in Kings County, were tested, one near the present shore of the lake and two about 5 miles from it. These waters contain considerably less dissolved constituents than the west-side waters of Fresno County, and they could be considered suitable for irrigation. They are high in sulphate, however, and the one farthest from the lake is a strong gypsum water.

Field work in the region south of Tulare Lake was not carried far enough west to make it certain that the true character of the ground waters in that part was discovered. A 20-foot dug well in sec. 1 (?), T. 24 S., R. 21 E., yields strong water high in sulphate, because it comes from the mineralized silt in the basin of Tulare Lake. No wells between that section and Semitropic could be sampled, but wells at the latter place yield water low in sulphate. Deep waters at Buttonwillow are low in sulphate, but those from wells 40 to 100 feet deep are high in sulphate, yet do not have the very high mineral content that is characteristic of ground waters in western Fresno County. Future investigation north and south of Lost Hills will probably show that the west-side belt of waters high in sulphate extends southward into Kern County, and that it terminates at its eastern boundary as abruptly there as in the counties farther north.

DEPOSITION OF CALCIUM SULPHATE.

The figures in Table 24 (p. 113) indicate that in general the ground waters near the western foothills are calcium sulphate waters and that those farther east are sodium sulphate waters, the former containing much more mineral matter than the latter. This highly interesting alteration in the ground supplies that flow from the foothills of the Coast Range toward the axis of the valley evidently is the result of deposition of gypsum while the waters are passing through the ground. This phenomenon can be made clearer by means of the data in Table 25.

TABLE 25.—*The deposition of calcium sulphate from west-side waters.*

[Parts per million.]

Constituents.	Fresno County, southern part.		Fresno County, northern part.	
	A.	B.	C.	D.
Bicarbonate radicle (HCO_3)	145	250	140	184
Sulphate radicle (SO_4)	1,160	420	1,720	470
Chlorine (Cl)	130	70	140	400
Total hardness as $CaSO_4$	1,410	340	1,900	270
Alkalies (computed)	240	240	360	470
Total solids (computed)	2,100	1,030	3,000	1,700

Column A gives the average of analyses of water from 7 wells 80 to 400 feet deep near the foothills southwest of Mendota in Fresno County and column B a similar average for 10 wells 20 to 1,100 feet deep in a strip east of the 7 wells but west of Kings River Slough. These averages indicate that during the eastward passage of the water carbonate increases at the expense of the chloride and the alkalies remain unchanged. The decrease in total solids, 1,070 parts, is equivalent to the decrease in total hardness expressed as calcium sulphate; furthermore, the decrease in sulphate, 740 parts, is equivalent to 1,050 parts of calcium sulphate, or almost exactly the decrease in total solids. These striking relations make it evident that gypsum is being deposited from the ground waters; for if the change were one of simple dilution other constituents would be proportionately decreased, and if the alteration in character were caused by reaction between alkali salts in the silt and the calcium salts dissolved in the waters sulphate would not be decreased and the alkalies would be greatly increased. The figures in columns C and D afford a similar comparison of waters from wells in the northwestern part of Fresno County, column C giving the average of analyses of water from four wells 200 to 280 feet deep far out on the plains and column D giving the mean of analyses of water from two wells 437 and 532 feet deep near San Joaquin River. The decrease in sulphate, equivalent to 1,700 parts per million of calcium sulphate, is not completely equaled

by the change of 1,630 in total hardness as calcium sulphate and of 1,300 in total solids, but these alterations are all of such magnitude in comparison with other changes that they lead to the conclusion that calcium sulphate is being deposited. North of Fresno County ground waters near San Joaquin River are affected in mineral content by seepage from the south and consequently any similar deposition that may occur there is effectually concealed.

COMPOSITION AND QUALITY OF AXIAL WATERS.

IRREGULARITY OF COMPOSITION.

The region of ground waters of the axial type can not be bounded so definitely as those of waters of the east-side and west-side types. It is included within the artesian area and it covers the territory between the boundaries indicated by A′A′ and C′C′ in Plate II (in pocket) overlapping on both sides and gradually merging into the areas in which other types predominate. As the axis of the valley or the lowest part of its trough receives the drainage of the valley ground waters there contain the highest proportion of the most readily soluble substances, the alkalies. On the west side sodium and potassium are left predominant among the bases after calcium sulphate has been removed from the ground water. On the east side the moderately mineralized calcium carbonate waters are strengthened by solution of alkali salts from the silts through which they slowly seep on their way from the foothills to the axis, and they are undoubtedly altered by drainage from irrigated lands. Carbonate is predominant on the east and sulphate on the west side of the axial belt, and both radicles are overshadowed by chloride in several localities. In general, the higher sodium content of waters from wells in the axis makes them less desirable for irrigation than that from wells on either side of the valley, and the same characteristic makes them more likely to foam when they are used for steaming.

The most noticeable feature of the axial waters is their wide range of concentration and composition, which is indicated in Plate V by graphic representation of the mineral content of water from wells of various depths in many localities. Nearly all wells in the axis near Tulare Lake yield sodium carbonate water, the deep supplies being much lower in mineral content than the shallower ones. Along Kings River Slough the mineral content of the ground waters is increased by the strong waters entering from the west side, and this influence continues northward for some distance along San Joaquin River.

CHLORIDE CONTENT OF ARTESIAN WATER.

Many deep wells along the axis north of Kings River yield brackish water, while wells away from the axis but just as deep and in the

same latitude do not; this indicates the existence of local saline deposits in the moderately deep silts and the downward percolation of water charged with the soluble constituents of the silts. Very deep wells invariably yield salt water, a condition that may be explained by the broadspread occlusion of saline waters within the deeper layers of silt. As this likelihood of striking distasteful salty water, harmful in irrigation and corrosive to boilers, is a discouraging feature about putting down deep wells into the abundant artesian flow near the river, Table 26 has been prepared giving certain data regarding artesian waters that were tested between Lemoore and San Joaquin Bridge.

TABLE 26.—*Chloride content of water from artesian wells between San Joaquin Bridge and Lemoore.*

Location.			Depth (feet).	Chlorine (Cl) (parts per million).	Quality for irrigation.	Quality for boiler use.
Sec.	T.	R.				
Del Puerto Orestimba.			480	295	Fair.	Very bad.
Do.			350	250	do.	Bad.
Do.			285	430	Poor.	Do.
26.	6 S.	9 E.	301	450	do.	Very bad.
31.	6 S.	10 E.	600	1,060	Bad.	Do.
6.	7 S.	10 E.	330	320	Poor.	Do.
25.	7 S.	10 E.	250	2,080	Bad.	Do.
17.	7 S.	11 E.	330	1,980	do.	Do.
13.	9 S.	9 E.	402	150	Good.	Bad.
20.	8 S.	11 E.	+500	1,520	Bad.	Very bad.
10.	8 S.	12 E.	297	10	Fair.	Fair.
16.	8 S.	13 E.	707	30	do.	Do.
27.	8 S.	14 E.	325	10	Good.	Do.
36.	9 S.	10 E.	350	139	Fair.	Bad.
36.	9 S.	10 E.	660	372	Poor.	Do.
14.	10 S.	11 E.	372	445	do.	Very bad.
Sanjon de Santa Rita.			320	35	Good.	Fair.
15.	9 S.	13 E.	300	25	do.	Do.
21.	9 S.	13 E.	340	20	Fair.	Do.
6.	10 S.	14 E.	283	25	Good.	Do.
30.	9 S.	15 E.	350	25	do.	Do.
21.	11 S.	12 E.	550	1,155	Bad.	Very bad.
1.	11 S.	12 E.	375	175	Fair.	Poor.
33.	11 S.	13 E.	437	685	Poor.	Very bad.
35.	9 S.	14 E.	240	20	Good.	Fair.
11.	10 S.	14 E.	400	30	do.	Do.
22.	13 S.	14 E.	532	115	Poor.	Very bad.
6.	13 S.	15 E.	520	1,680	Bad.	Do.
34.	11 S.	16 E.	+300	25	Good.	Fair.
32.	11 S.	18 E.	1,310	1,160	Bad.	Very bad.
31.	13 S.	15 E.	640	75	Fair.	Bad.
10.	14 S.	16 E.	550	245	do.	Do.
12.	15 S.	16 E.	700	65	Good.	Do.
19.	15 S.	16 E.	700	55	Fair.	Do.
25.	15 S.	17 E.	750	155	Poor.	Do.
9.	15 S.	17 E.	800	265	do.	Do.
14.	16 S.	17 E.	690	150	do.	Do.
8.	17 S.	17 E.	1,100	35	Good.	Poor.
15.	17 S.	18 E.	600	125	Poor.	Bad.
2.	17 S.	18 E.	1,200	135	do.	Do.
36.	18 S.	18 E.	1,178	40	Fair.	Do.
28.	18 S.	20 E.	700	20	Poor.	Poor.
14.	18 S.	18 E.	2,250	280	do.	Bad.

Thirteen artesian waters along Kings River Slough and within 6 miles of that watercourse were tested. (See Table 26.) Among these the water from the 2,250-foot well in T. 18 S., R. 18 E., containing 280 parts of chlorine, is practically useless. The water of a 550-foot well at Jamesan and of an 800-foot well south of that station are rather

high in chlorine. The other ten waters, from wells 600 to 1,200 feet deep, are moderately low in chlorine and good to poor for irrigation, but undesirable for boiler use because of their high contents of foaming ingredients. Nearly all the artesian waters from wells less than 1,000 feet deep east of San Joaquin River and south of Dickersons Ferry are low in chlorine and are suitable for common use, but those west of the river in the same latitude are much poorer. Water from the 1,310-foot well in T. 11 S., R. 18 E., is high in chlorine and bad for general use. All deep waters around Newman and Stevinson Colony contain much chlorine. This condition extends south to Dickersons Ferry and north to Crows Landing, and probably no wells in that territory more than 300 feet deep will yield really satisfactory water. Water from shallow wells in Stevinson Colony is much better than that from deep wells.

No well more than 200 feet deep could be found between Crows Landing and Lathrop and therefore the quality of the deep axial waters in that area are unknown. The water of the 480-foot well at Crows Landing carries 295 parts per million of chlorine and is only fair for irrigation. The water of a 1,200-foot well near French Camp, just north of Lathrop, contains 1,735 parts of chlorine and is unfit for irrigation. Wells more than 1,200 feet deep at Stockton yield salt water while those 700 to 1,100 feet deep yield fresh water fair or poor for irrigation and shallower wells yield satisfactory fresh water.

The 1,310-foot well near Madera yields water containing 1,160 parts per million of chlorine. Therefore it may be concluded that any well more than 1,200 feet deep between Dickersons Ferry and Suisun Bay will yield salt water unsuitable for use. As the analyses show that the water of wells more than 400 feet deep near the axis between Dickersons Ferry and Crows Landing is salty and poor in quality, it is reasonable to conclude that wells 400 to 1,200 feet deep near the axis between Crows Landing and San Joaquin Bridge will also yield salty water. A similar conclusion regarding 500 to 1,000-foot wells 10 miles or more east of the river in Stanislaus and San Joaquin counties is, however, unjustifiable by the data at hand. It is possible that fresh water may be encountered between those depths as in eastern Merced and Madera counties, but no assertion to that effect can be made.

INCREASE OF MINERAL CONTENT FROM SOUTH TO NORTH.

GENERAL CONDITIONS.

Structurally, San Joaquin Valley is a trough filled with silt from the surrounding mountains. The ground waters, following the gentle but definite slope, percolate toward the axis and then follow the axis northward. They dissolve and retain in solution the more readily soluble substances with which they come into contact, and

some of them deposit part of their load of less soluble constituents. These conditions lead to belief that the ground water gradually increases in mineral content as it progresses northward, or, in other words, that analyses of water from wells of equal depth should indicate an increase of mineral content from south to north. It is the purpose of this section to show how far the results of the tests support that belief.

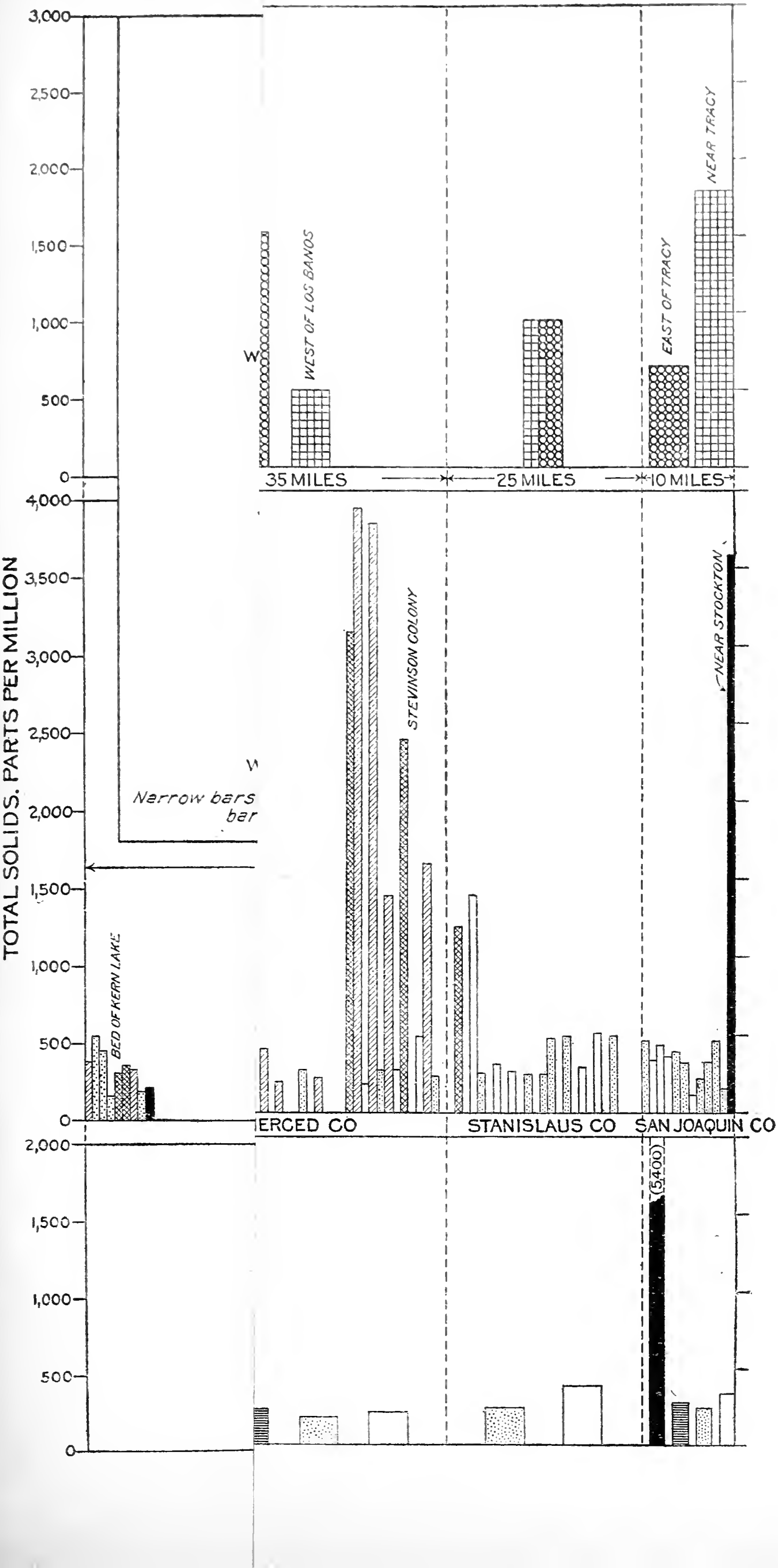
Plate V shows graphically the amount of mineral matter in ground waters in different parts of the valley. Averages of analyses grouped by depth of wells have been used for the east side in order that the changes from county to county might be more clearly shown, but the results of individual tests have been plotted in the axis because the total solids there are so divergent. The only feasible grouping of analyses on the west side is by location. The length of the blocks indicates the amount of total solids and the shading indicates the depth of the wells. For the purposes of this diagram it has been convenient to accept the boundaries indicated by A′A′ and C′C′ in Plate II (in pocket) as the limits of the respective areas.

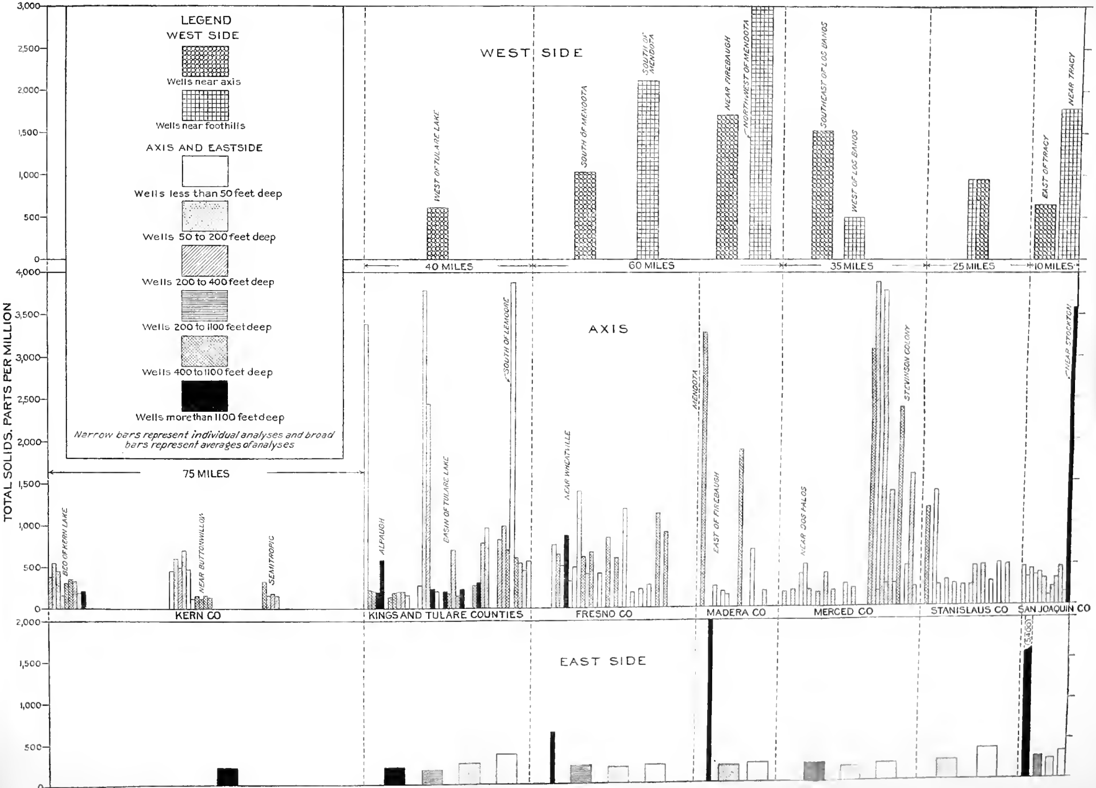
The diagram as a whole shows simply and forcibly the relations between location, depth, and mineral content of the ground waters. The east-side waters, low in mineral content, are remarkably uniform in quality down to a certain depth. The west-side waters are much more highly mineralized and are differentiated from each other principally by their distance from the foothills. The axial waters, extremely variable in character, are influenced by east-side and west-side waters and by soluble constituents in local sediments. The relations represented diagrammatically in Plate V explain several apparently inconsistent conditions of quality.

Briefly, the data establish that a progressive increase in the mineral content of the deep-seated underground drainage takes place, especially near the axis of the valley. No such relation exists in respect to the shallow waters, however, even near the median line of the trough, where the influence would be most clearly evident.

DEEP WATERS.

Analyses of water from wells more than 1,100 feet deep show a definite increase in mineral content from south to north proportionate to the increase in alkalies and chlorine; that is, the waters become more salty toward the outlet of the valley. Wells on the east side of Kern, Kings, and Tulare counties from 1,100 to 2,000 feet deep yield excellent water averaging about 200 parts per million of total solids. The water of the 1,200-foot well in sec. 2, T. 17 S., R. 18 E. is moderate in solids and in chlorine; the salty water of the 1,310-foot well in sec. 32, T. 11 S., R. 18 E. contains more than three times


TOTAL SOLIDS. PARTS PER MILLION
3,000
2,500
2,000
1,500
1,000
500
0
4,000
3,500
2,000
WEST OF LOS BANOS
EAST OF TRACY
NEAR TRACY
35 MILES
25 MILES
10 MILES
STEVINSON COLONY
NEAR STOCKTON
BED OF KERN LAKE
Narrow bars
bar
ERCED CO
STANISLAUS CO
SAN JOAQUIN CO
(5400)



MINERAL CONTENT OF GROUND WATERS IN SAN JOAQUIN VALLEY.

as much mineral matter; and the waters that were tested from wells more than 1,100 feet deep in San Joaquin County average 5,200 parts per million in mineral content. These data indicate a decided northward increase beginning in Fresno County in the mineral content of the deep waters, a conclusion that is corroborated by the few available tests of deep ground waters in the axis. The 2,250-foot well in sec. 14, T. 18 S., R. 18 E., included among the axial waters, yields poor water, and the 1,200-foot well at French Camp furnishes a supply comparable with the deep waters at Stockton.

OCCLUSION OF SEA WATER.

Though it has been suggested that this increase of solids, representing increase of chloride and alkali, is evidence of the occlusion of sea water within the deep sediments, the composition of the waters makes this improbable. Sea water contains 33,000 to 37,000 parts per million of mineral matter in solution, while the water of a 1,786-foot well at Stockton contains 4,700 parts, that of a 2,500-foot well at Stockton 7,489 parts, and that of the 1,200-foot well at French Camp only 3,000 parts. Besides this striking difference in concentration the figures in table 27 prove that the composition of the mineral matter is also entirely different from that of sea water. The analysis of water from the 2,500-foot gas well at Stockton has been selected for comparison because it is the strongest water and because as much as possible of the upper fresh waters has been excluded. Even if the deep water had been diluted through a leaky casing the composition of it could not have been so radically changed from that of sea water.

TABLE 27.—*Comparison of the composition of water from a 2,500-foot well at Stockton with that of sea water.*

[Percentage of anhydrous residue.]

Constituents.	Well.[a]	Ocean.[b]
Silica (SiO_2)	0.72	
Calcium (Ca)	10.72	1.20
Magnesium (Mg)	3.24	3.72
Sodium and potassium (Na+K)	22.40	31.70
Carbonate radicle (CO_3)	.64	.21
Sulphate radicle (SO_4)	.00	7.69
Chlorine (Cl)	62.28	55,29
Salinity (parts per million)	7,489	33,010 to 37,370

[a] Silica not determined. Estimated for purposes of computation as 50 parts. Analysis by F. M. Eaton, Sept. 19, 1910.
[b] Average of analyses by Dittmar; quoted by Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 616, p. 123, 1916. Minor ingredients omitted.

These waters are similar only in that they are both strong solutions of sodium chloride. The ratio (1 to 3.3) between the amounts of calcium and magnesium in the well water is that of ordinary ground water and is the reverse of that in sea water (3.1 to 1). This fundamental difference and the undoubted absence of any appreciable

quantity of sulphate in the well waters, whereas the residue of ocean water contains nearly 8 per cent of sulphate, makes it entirely improbable that the saline character of the deep-seated supplies is due to the retention of ocean water within the valley sediments. It is more reasonable to believe that the salt represents an accumulation derived from the silts through which the water has very slowly passed.

SHALLOW WATERS.

Waters from wells 400 to 1,100 feet deep in the axis of the valley increase from south to north in mineral content, but on the east side waters from wells of similar depth are slightly mineralized and are much alike in composition irrespective of their position. Shallower waters show great local diversity of composition in the east side and in the axis. No regular relation holds for supplies of this class, and their quality is predictable only from local tests.

On the west side local conditions determine the quality of ground waters, in which no regular increase of mineral content from south to north is apparent. The mineral content of waters on the west side is highest in Fresno County, and it decreases northward, rising somewhat near the foothills in San Joaquin County. The total solids of ground waters near the west shore of Tulare Lake are less than those of supplies in Fresno County, but it is unknown whether that condition prevails in the west side of Kern County.

RELATION OF DEPTH TO MINERAL CONTENT.

It is a fairly prevalent belief that the deeper a well goes the greater is the mineral content of its water. Yet a little thought establishes the unreasonableness of such general assumption, and a cursory review of analytical data is sufficient to prove the fallacy of it. The mineral content of a ground water depends primarily on the kind of rock with which it comes into contact, and its chemical composition at any stage in its progress tells the main facts of its history. Pressure, temperature, and duration of contact, the physical structure of the rocks, and the nature of substances previously dissolved in the water influence the extent and the manner in which minerals are acted on by the solvent, but the effect of these conditions is subordinate to that of the chemical composition of the rocks themselves, which is the chief determining factor of the mineral content of ground water. It is therefore not at all rare to find deep waters better than shallow ones. Many wells 1,000 to 3,000 feet deep in sedimentary rocks penetrate strata yielding widely different kinds of water, but without any relation to depth except in so far as depth has reference to the character of the rocks that contain the supplies. Indeed, these facts are so nearly self-evident that it would be needless to state them

if belief in a general relation between depth and quality were not so frequently expressed.

Differences in the quality of water from various depths can be detected in almost every locality in San Joaquin Valley, but they are not regular and can not be widely generalized. Nearly all the best waters on the east side are produced by wells 200 to 1,000 feet deep. They are generally good for irrigation, fair for boiler use, and entirely acceptable for domestic supply. On the east side it is not unusual to find the water from wells 10 to 30 feet deep much harder than that from deeper wells. Similar greater mineral content of shallow waters from glacial deposits derived from calcareous formations in the Central States has been noticed, and it is probably due to more rapid mechanical disintegration of the layers nearest the surface and to greater abundance of solvents like carbon dioxide in the upper waters.

Geographical location has more influence than depth on the mineral content of well waters on the west side a few miles from the river, for the differences of composition among the waters at various depths are not so great proportionately as on the east side.

The relations between depth and quality are more uncertain along the axis than in any other part of the valley. For example, wells 30 to 100 feet deep in Stevinson Colony yield fresh water of moderate mineral content, but wells more than 300 feet deep yield undesirable salt water. On the other hand, water from wells less than 100 feet deep near Tulare Lake is highly alkaline, and the best supplies are obtained from wells 800 to 2,000 feet deep.

QUALITY FOR IRRIGATION.

EAST-SIDE WATERS.

Almost no trouble from poor quality of ground waters for irrigation has been reported throughout the east side of the valley, and available analyses amply confirm the results of experience besides indicating more territory into which this application may be extended. Wells generally throughout the east side yield water that is good or fair for irrigation—the supplies may be used year after year with only moderate care to prevent alkali accumulation due to the mineral constituents of the waters. This statement should be supplemented by the warning that the soil in many sections already contains enough alkali to interfere with cultivation under ordinary conditions and that water of any quality, no matter how good, can not assist in producing full crops on such areas until the excess of sodium salts in the ground has been removed by drainage or by some other means. It is therefore important to note that statements regarding the quality of waters for irrigation refer only to the action of the mineral ingredients of the waters in reducing or increasing the

mineral content of the soil solution. On the other hand, notes of the actual effect of the waters on crops involve all growing conditions, such as the nature of the ground, the care given the crops, and other features; consequently a statement that crops have not flourished after having been irrigated by a certain water does not necessarily imply that the mineral constituents of the water did the damage.

The best waters for irrigation on the east side are furnished by wells 200 to 1,000 feet deep, though a large number of shallow wells also are utilized. Within the artesian area south of Kings River water from wells as deep as 1,600 to 2,000 feet is satisfactory and has been used on crops. North of Fresno water from wells more than 1,000 feet deep is poor, and near the northern end especially it is unfit for irrigation. Four waters that were tested from wells 1,200 to 2,500 feet deep in and around Stockton are bad because they are strongly saline. Tests of the deep wells at the waterworks, a 1,162-foot well, and a 1,010-foot well near Stockton indicate that sodium replaces calcium as the predominant base at a depth of about 900 feet and consequently that the ground waters become progressively poorer from that depth down to about 1,200 feet where the salty supplies are struck. So few deep wells could be tested south of San Joaquin County that it is uncertain how far southward this condition extends, but it seems reasonable to assume that it is general over the east side between Stockton and Fresno.

WEST-SIDE WATERS.

Wells are being pumped for irrigation at several places on the west side of the valley, and continued settlement of that region will undoubtedly result in greatly increased use. The ground waters of the west side, being much more highly mineralized than those of the east side, are poorer for irrigation. Few of those that were tested, however, are so bad that they are absolutely unfit for use, a fact all the more important because the absence of perennial streams and other surface supplies capable of being stored on the mountain slopes makes the adoption of ground supplies a necessary feature of utilizing the lands. Though the mineral content of the waters is high, the principal ingredients away from the axis are calcium, magnesium, and sulphate, the toxic alkalies being relatively low. Water of this calcium sulphate type can be applied to land without injury at far greater concentrations than are allowable for sodium waters; indeed, calcium sulphate in the form of gypsum or "land plaster" is often spread on fields to neutralize the deleterious effect of black alkali.

Several tracts in western Fresno County now being irrigated by well water have not been under cultivation long enough fully to demonstrate the value of the waters, but sufficient time has elapsed

to make it apparent that selected crops under proper care can be raised. The results at the pumping stations of the Pacific Coast Oil Co., where lawns, fruit trees, and garden truck have been irrigated for several years, also give favorable testimony as to the feasibility of utilizing the west-side waters.

AXIAL WATERS.

Calcium and magnesium are the predominant bases in the typical waters of both sides of the valley, but they gradually become subordinate toward the axis, where the alkalies, sodium, and potassium, occur in greater quantity. This alteration takes place more or less generally within the limits of the artesian area, and it is practically complete within the boundaries indicated by lines A′A′ and B′B′ of Plate II. Because of this alteration the axial waters are least desirable for irrigation, and further development of irrigation on both sides of the valley, with resultant increase of the more readily soluble constituents in the ground supplies, will probably make the axial waters still poorer and will also cause greater accumulation of alkali there in the soil. This probability that the axis will eventually become the sewer for the rest of the valley suggests that safe cultivation of the ground there will necessitate the construction of dikes and underdrains for the purpose of removing the alkali and preventing undue rise of the ground-water level. Water from artesian wells 1,400 to 2,000 feet deep close to the present shore of Tulare Lake is being successfully used for irrigating alfalfa, grain, and other crops, but many wells less than 400 feet deep in that region yield unsatisfactory supplies. Tests of water from wells 300 to 600 feet deep in Stevinson Colony indicate that the water is bad for irrigation, and attempts to use it in crops have been unsuccessful. It is understood that a similar failure followed use of some of the deep waters in Jamesan Colony.

RESULTS OF USING GROUND WATERS.

The character, mineral content, and classification of some supplies that have been applied to crops in San Joaquin Valley are presented in Table 28 in order to give a general idea of the kinds of water that are available. The tests have been grouped for convenience under three headings. Reference may be made to the tables of assays (pp. 182–294) for information regarding the value of other local waters for irrigation. The quality for irrigation has been computed from the analytical data and it is followed by a statement regarding the result of applying the waters to crops. Where no information is given other than that certain cultures have been irrigated it may be understood that those cultures have been irrigated for several consecutive years without apparent ill effect due to the quality of the water.

TABLE 28.—*Types of ground water in San Joaquin Valley and their value for irrigation.*

East side.

Total solids (parts per million).	Chemical character.	Quality for irrigation.	Results of use in irrigation.
160	$Ca-CO_3$	Good	Irrigates alfalfa and sorghum.
160	...do	...do	Irrigates alfalfa.
180	...do	...do	Irrigates grapes.
190	...do	...do	Irrigates peaches.
190	...do	...do	Irrigates grapes and alfalfa.
190	...do	...do	Irrigates grapes.
200	...do	...do	Has irrigated garden several years.
200	...do	...do	Irrigates garden.
210	...do	...do	Do.
230	...do	...do	Irrigates olive trees.
250	...do	...do	Irrigates alfalfa.
258	...do	...do	Irrigates orange trees.
260	...do	...do	Has irrigated oranges 6 years.
400	...do	...do	Irrigates garden.
140	$Na-CO_3$	...do	Irrigates alfalfa, garden, and fruit trees.
150	...do	...do	Has irrigated grapes, alfalfa, and garden several years.
150	...do	...do	Irrigates alfalfa.
160	...do	Fair	Used several years on alfalfa.
170	...do	...do	Successfully used on grapes and alfalfa.
170	...do	...do	Successfully used on alfalfa and fruit trees.
200	...do	...do	Irrigates alfalfa.
220	...do	...do	Used on garden truck 30 years without trouble.
230	...do	...do	Irrigates alfalfa.
300	...do	...do	Irrigates fig, peach, and other fruit trees.
370	...do	...do	Used generally in city for lawns and gardens.
390	...do	...do	Do.
2,000	Na-Cl	Bad	Destructive to crops.

Axis.

372	$Ca-CO_3$	Good	Irrigates orange trees.
130	$Na-CO_3$	...do	Irrigates lawn and garden.
130	...do	...do	Has irrigated alfalfa, cabbages, and garden truck 18 years.
130	...do	...do	Irrigates lawn, garden, and trees.
140	...do	...do	Irrigates grain and alfalfa.
140	...do	...do	Irrigates alfalfa.
150	...do	...do	Do.
170	...do	...do	Used several years on alfalfa.
190	...do	...do	Irrigates orchard and garden.
190	...do	Fair	Used 3 years on alfalfa, grapes, and peaches.
200	...do	Good	Irrigates garden and fruit trees.
200	...do	Fair	Irrigates alfalfa.
210	...do	...do	Used on alfalfa several years.
218	...do	Good	Irrigates melons, grapes, and garden truck.
220	...do	Fair	Irrigates alfalfa, grapes, and garden truck.
220	...do	...do	Irrigates asparagus.
260	...do	...do	Irrigates alfalfa.
700	...do	Poor	Used on alfalfa, garden, and orchard to some extent in 2 years without bad effect.
1,200	...do	Fair	Irrigates garden.
2,300	...do	Bad	Kills grass around well.
600	$Na-SO_4$	Fair	Has irrigated vegetables and berries 8 years.
980	...do	Poor	Used 1 year on garden.
300	Na-Cl	Fair	Irrigates alfalfa.
310	...do	...do	Irrigates wheat and alfalfa.
670	...do	Poor	Used successfully on alfalfa.
810	...do	...do	Said to kill vegetation.
1,210	...do	...do	Has been used on grain and alfalfa. Not now used.
1,600	...do	...do	Garden truck did not grow well when irrigated with water. Tomatoes grew smaller each year.
2,400	...do	Bad	Tried unsuccessfully on crops.

West side.

410	$Ca-CO_3$	Good	Irrigates lawn and trees.
620	$Na-SO_4$	...do	Irrigates garden and small fruit trees.
950	...do	Fair	Irrigates lawn and trees.
1,600	...do	...do	Has irrigated wheat and barley 2 years.
1,200	$Ca-SO_4$	Good	Irrigates lawn and trees.
1,500	...do	...do	Has irrigated alfalfa, cotton, and garden truck successfully for 1 year.
2,400	...do	Fair	Has irrigated barley 1 year.

The data in Table 28 prove that the nature as well as the quality of the dissolved matter has much to do with its effect. Waters containing as much as 1,200 to 2,400 parts per million of total solids, the chief constituents of which are calcium and sulphate, have been successfully applied to cultures. This quantity of mineral matter is greater than the maximum considered allowable in California under the ordinary practice by Hilgard,[1] who evidently has alkali waters especially in mind. Continued use of these stronger waters will undoubtedly involve careful selection of crops and installation of underdrainage to prevent excessive accumulation of alkali. Many sodium carbonate or black alkali waters are being used without apparent trouble near the center line of the valley, but they are all rather low in mineral constituents, total solids being 140 to 400 in the best waters and exceeding 800 parts per million in only a few. It is fortunate that the deep waters east of Tulare Lake are low in mineral matter, as they belong to the sodium carbonate class. The calcium carbonate waters, ranging in this valley usually from 150 to 400 parts per million of solids, can be used without any trouble, and they are classed as good or fair for general irrigation.

EFFECT OF COLD WATER.

The slow development sometimes reported regarding cultures irrigated with ground water on the east side may be caused by the low temperature of the water when it reaches the feeding rootlets, a condition that is undesirable particularly during early stages of growth. Cold water has its greatest retarding effect when it is applied by flooding or by "basin irrigating," as the method of running water into shallow pools around the trunks of bushes and trees is known. When the water is applied through furrows it has opportunity to become warm before it reaches the delicate roots, and the harmful consequences of low temperature are thus avoided. The same result can be obtained by storing the supplies in reservoirs, though this occasions some loss by evaporation. It is customary in many districts to pump into reservoirs during the day and to distribute the supply during the night, when the loss by evaporation is less and more water can therefore be absorbed by the ground, which also does not bake so badly on the surface after the downward percolation. The chill is taken from the water during this storage and subsequent damage is obviated.

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[1] Hilgard, E. W., Soils, p. 248, The Macmillan Co., New York, 1906.

QUALITY FOR INDUSTRIAL USE.

INDUSTRIAL DEVELOPMENT.

Two transcontinental lines traverse the valley from end to end, comprising, with their branches and some shorter systems, about 1,400 miles of track, along which the consumption of water by locomotives is over 3,000,000 gallons a day. Most of this mileage is on the east side of the valley, where the best waters for boiler use are found, but two or three lines already enter the west side, and agricultural development there will soon necessitate more extensive transportation facilities. The numerous wineries in the vineyard districts, particularly around Stockton and Fresno, use large quantities of water for steam making and for washing vats and bins. Ice factories are operated in the larger cities, where laundries and breweries also are important consumers.

EAST-SIDE WATERS.

The ground waters of the east side are generally suitable for boiler use without purification. As they belong mostly to the calcium carbonate type and contain practically no sulphate and rarely much chloride, they are not likely to foam or to be corrosive. The quantity of scale-forming ingredients ranges from 90 to 300 and of foaming ingredients from practically nothing to 250 parts per million. The supplies are generally good or fair for boiler use, form a soft scale, and do not require boiler compounds.

Table 29 contains a summary of tests of east-side industrial supplies particularly in reference to boiler use. The softest supplies supplies almost everywhere on the east side are obtained from wells 200 to 1,000 feet deep. Water from many wells less than 50 or 60 feet deep contains more scale-forming matter than that from deeper wells, and it is therefore less desirable for industrial use. This condition may be demonstrated by comparison of analyses at Stockton, Merced, Fresno, and Tulare, and, though it is not invariable, it is near enough so to make it worth while to investigate the quality of deeper waters before extensive industrial development is undertaken in unexplored localities. Wells more than 1,200 feet deep at Stockton, French Camp, and Madera yield salt water unfit for boiler use, and all wells of that or greater depth on the east side as far south as Fresno will probably yield bad water. Wells of the same depth in Tulare County, however, yield supplies that are very low in scale-forming ingredients, noncorrosive, and low enough in foaming constituents to be classed as good or fair for boiler use. Some ground waters on the east side, more commonly shallow ones, contain enough iron to make them

industrially undesirable. This type of water is avoidable, however, and water of acceptable quality may be obtained nearly everywhere on the east side.

WEST-SIDE WATERS.

The west-side supplies are very hard calcium sulphate waters. They form hard refractory scale in boilers, and many of them are corrosive, and consequently as a class they are undesirable for boiler use. The most highly mineralized sources were found in the west side of Fresno County and in the south part of western Merced County. It is understood that very bad boiler waters also are encountered west of Buttonwillow in Kern County. Few of the waters used in boilers on the west side belong in the calcium sulphate class, for most of them are near enough to the axis to be predominant in alkalies. In order to avoid confusion, however, those from wells in the territory west of the boundary indicated by A′A′ in Plate II have been entered in Table 29 as west-side waters.

The quantity and hardness of the scale produced generally by west-side waters are such that softening is necessary before introduction of the waters into boilers. The Southern Pacific Co. treats 300,000 to 350,000 gallons of water daily at Tracy and about 30,000 gallons at Westley, and avoids the use of ground water at Los Banos, Firebaugh, and Mendota by pumping from San Joaquin River. The water at Tracy is treated with lime and soda ash in a cold-water softening plant, about two-thirds of the incrusting matter being removed. The supply at Westley, fairly high in incrustants and in foaming constituents, is softened by means of lime, the sludge being dumped on the ground near the tanks. The supply at the ice factory of the Newman Light and Power Co. at Newman gives a large amount of hard scale even after having been passed through an open heater with a filtering attachment. Though the railroad supply at that place is much lower in incrustants it contains nearly as great quantity of foaming ingredients, and the city water is like the railroad supply. Experience at the pumping stations along the pipe line of the Pacific Coast Oil Co. is valuable not only in showing the normally poor quality of the west-side waters for boiler use but also in demonstrating how much can be done to improve them by scientific treatment. The pipe line, after entering the west side a few miles north of Tulare Lake, traverses it from south to north at a distance of 5 to 10 miles from the axis. Most of the boiler supplies along the line are of sodium sulphate character—that is, sodium and sulphate are the chief ingredients, but the waters also contain much calcium and magnesium. This makes them capable of forming considerable hard scale and of foaming when they are concentrated; altogether they

range from poor to very bad for boiler use in the raw state. It is general practice at the pumping stations to remove a large part of the incrusting matter by treating the supplies with soda ash in open heaters. The tendency to foam is increased in proportion to the quantity of soda ash added, but trouble from that source is obviated by frequent blowing off. The boilers are cleaned regularly every three weeks or oftener, and this attention coupled with the preliminary treatment makes it possible to utilize the waters without trouble or danger. The waters still farther west, however, are generally much higher in incrustants, and many of them are so hard that they could not be rendered fit for use by any treatment except distillation.

AXIAL WATERS.

Excellent supplies for boilers can be obtained from deep wells between Tulare Lake and the city of Tulare in Kings and Tulare counties. Several waters near Corcoran and Angiola produce almost no scale and can be strongly concentrated without trouble from foaming or corrosion.

RESULTS OF USING GROUND WATERS.

The more important facts in reference to the industrial supplies of the valley are summarized in Table 29. More complete details of the analyses can be obtained from the analytical tables (pp. 182–294). The analyses have been grouped for convenience under three headings and by chemical character.

TABLE 29.—*Some industrial water supplies in San Joaquin Valley.*

[Parts per million except as otherwise designated.]

East side.

Scale-forming ingredients (s).	Foaming ingredients (f).	Probability of corrosion (c).[a]	Character of water.	Quality for boilers.	Remarks.
140	10	N. C.	Ca-CO_3	Fair	Used in wine making and in boilers. Wash boilers once a week and get soft sludge. No compound used.
90	40	N. C.	...do	Good	Used in boilers.
115	40	N. C.	...do	Fair	Used in beer making and in boilers. Some compound used.
130	40	N. C.	...do	...do	Used in wine making and in boilers. Clean boilers once in 3 months. A little sludge removed. Blow one gage in 24 hours. Use skimmer. No compound used.
135	50	N. C.	...do	...do	Locomotive supply.
150	40	N. C.	...do	Good	Boiler supply. Clean boilers once a week, getting 7 to 8 pounds hard scale and some sludge. No compound used.
160	20	N. C.	...do	Fair	Distilled for ice making. Little sludge in boilers. Practically no scale on atmospheric condensers in 4 months.
125	80	N. C.	...do	...do	Locomotive supply.
155	60	?	...do	...do	Do.
100	10	?	...do	Good	Distilled for ice making. Little sludge.
190	90	?	...do	Fair	Locomotive supply.
300	30	?	...do	Poor	Do.
200	140	?	Ca-SO_4	Fair	Do.
300	160	?	...do	Poor	Do.
60	80	N. C.	Na-CO_3	Good	Do.
100	80	N. C.	...do	Fair	Boiler supply. Clean every 2 weeks. Eggshell scale; no corrosion; no compound used; blow one-half gage two or three times each shift.
105	100	N. C.	...do	...do	Locomotive supply.
40	250	N. C.	Na-Cl	...do	Do.

Axis.

70	80	N. C.	Na-CO_3	Good	Boiler supply. Practically no scale. No treatment; no corrosion. Blow once in 24 hours.
70	80	N. C.	...do	...do	Boiler supply. Cochrane heater. No chemicals. Practically no scale.
70	180	N. C.	...do	Fair	Used in 1,250 H. P. boilers. No scale; no pitting.
50	70	N. C.	Na-Cl	Good	Boiler supply. No trouble; no treatment.

West side.

260	90	?	Ca-CO_3	Poor	Boiler supply. Use soda ash and Cochrane heater. Boilers cleaned every 3 weeks. Blow 2 gages every 12 hours.
700	270	C.	Ca-SO_4	Very bad.	Boiler supply. Use soda ash and Cochrane heater.
400	350	?	Na-SO_4	Bad	Boiler supply. Boilers cleaned once a month. Scale hard, brittle, about $\frac{1}{16}$ inch thick. Blow 1 gage every 24 hours. Soda treating plant being installed.
250	220	?	...do	Poor	Locomotive supply. Cold water softener with lime and soda ash used.
260	840	?	...do	Very bad.	Boiler supply. Use soda ash and Cochrane heater. Clean every 18 days. Get 60 to 70 pounds eggshell scale.
125	1,000	N. C.	...do	...do	Boiler supply. Use soda ash and Cochrane heater. Scale thin, but hard and tough.
230	790	N. C.	...do	...do	Boiler supply. Treated with soda ash.
160	380	N. C.	...do	Bad	Boiler supply. Use soda ash and Cochrane heater. Clean every 3 weeks. Blow once a day.
105	500	N. C.	...do	Very bad.	Boiler supply. Use soda ash and Cochrane heater. Clean once in 3 weeks. Blow twice in 24 hours.
500	650	?	Na-Cl	...do	Distilled for ice making. Open heater and compound. Large amount of hard scale.

[a] N. C.=Noncorrosive; C=corrosive; ?=corrosion uncertain or doubtful.

QUALITY FOR DOMESTIC USE.

DEPTH AND POSITION OF POOR SUPPLIES.

Wells more than 1,200 feet deep in and near Stockton yield salt water unsuitable for domestic use, and though the available information indicates that the salinity decreases southward all wells 1,200 feet or more in depth as far south as Fresno probably yield salty water. Though some shallower supplies on the east side of the valley are moderately hard they are not excessively so, and they are generally acceptable for domestic use.

Water fit to drink can not be obtained from wells close to the foothills in the southwest part of Kern County and at some places in western Fresno County. The highly gypsiferous waters of western Fresno County can not be used for cooking vegetables and they are nauseating to some persons. With the exception of these areas, however, potable ground water can be obtained from wells throughout the west side. They are, as a rule, very hard, and the traveler who is not accustomed to drinking alkali water can readily notice the distinct taste of the supplies west of San Joaquin River. They are not injurious, however, except in the localities just mentioned, and many of the strongly mineralized ones have been used without harm for several years.

All the artesian waters north of Lemoore, except those containing enough chloride to be salty, are suitable for domestic use. The location of the chloride-bearing waters and the extent of the areas likely to yield such supplies are discussed on pages 117–119. Water from some wells less than 300 feet deep close to Tulare Lake is too strongly impregnated with black alkali to be potable. A few waters just south of Lemoore are highly colored and have a peculiar taste, probably because of percolation through buried peat or other vegetable matter. The deeper supplies around Tulare Lake are exceptionally soft and low in all mineral ingredients and they are very good for domestic use.

POSSIBILITY OF POLLUTION.

The close-grained texture of the silt deposits in San Joaquin Valley, the consequent slow movement of the ground waters, and the general practice of boring wells and casing them form effectual safeguards against pollution by surface drainage or seepage from privies and cesspools a reasonable distance away. Dug wells, so often exposed to contamination, form a small proportion of the domestic supplies because of the uncertainty of obtaining sufficient water at the shallow depths to which such wells can be sunk. If bored wells are constructed with care to insure tight casings to a depth of 40 or 50 feet and if the collection of stagnant water or filth around the top of the casing is prevented, there is little danger of pollution.

MUNICIPAL SUPPLIES.

Cities on the west side near San Joaquin River could avoid troubles incident to the use of hard ground water and could more readily attract prospective manufacturers by drawing from San Joaquin River and its eastern tributaries. Such surface supplies would, of course, have to be filtered, for the streams are subject to pollution by general infiltration, some sewage, and drainage from irrigated lands, but purification would be comparatively simple, and the resulting water would be clear, colorless, and tasteless and extremely low in alkalies and hardness.

Almost all the cities of the valley are supplied with ground water. The composition of the supplies of which analyses are available is given in Table 30.

TABLE 30.—*Chemical composition of some municipal water supplies in San Joaquin Valley.*

[Parts per million except as otherwise designated.]

City.	County.	Depth of well (feet).	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).
Alpaugh	Tulare	2,000						Tr.	266
Corcoran	Kings	1,000						9	99
Dinuba	Tulare	278						0	164
Exeter	do	100	[b] 39		26	9	32	0	144
Lodi	San Joaquin		[b] 60		28	11	26	0	130
Mendota	Fresno	640						Tr.	147
Modesto	Stanislaus		[b] 50		38	10	63	0	110
Newman	do	396 398		0.40	66	37	[a] 238	0	189
Oakdale	do		[b] 30		27	12	13	0	120
Portersville	Tulare	200						0	200
Stockton	San Joaquin	([c])		.12	17	7.0	[a] 86	0	205
Do	do	([d])	[b] 48		23	11	84	0	242
Do	do	([e])	57	.03	6.1	7.2	89	0	210
Tulare	Tulare	([f])	[b] 16		14	1	24	0	90
Do	do	800		.25	29	4.0	[a] 18	0	122

City.	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total solids.	Chemical character.	Analyst.	Date.
Alpaugh	5	180	154	[a] 560	Na-Cl	R. B. Dole	Nov. 25, 1910
Corcoran	Tr.	15	29	[a] 180	Na-CO_3	do	Nov. 22, 1910
Dinuba	Tr.	40	148	[a] 260	Ca-CO_3	do	Nov. 18, 1910
Exeter	11	27	[a] 100	215	do	Southern Pacific Co	Dec. 29, 1904
Lodi	7	36	[a] 115	236	do	do	May 4, 1908
Mendota	430	75	83	[a] 910	Na-SO_4	R. B. Dole	Nov. 1, 1910
Modesto	3	127	[a] 135	344	Na-Cl	Southern Pacific Co	July —, 1900
Newman	125	389	[a] 310	1,016	do	F. M. Eaton	Oct. 13, 1910
Oakdale	14	20	[a] 115	175	Ca-CO_3	Southern Pacific Co	Oct. —, 1900
Portersville	Tr.	20	160	[a] 250	do	R. B. Dole	Nov. 21, 1910
Stockton	0	64	[a] 71	350	Na-CO_3	F. M. Eaton	Sept. 18, 1910
Do	5	59	[a] 105	349	do	D. B. Bisbee	Dec. 3, 1904
Do	7.1	35	[a] 45	306	do	Walton Van Winkle	Oct. 1, 1910
Tulare	3	8	[a] 40	111	do	Southern Pacific Co	Apr. 2, 1902
Do	14	9.0	[a] 90	174	Ca-CO_3	F. M. Eaton	Nov. 14, 1910

[a] Computed.
[b] Including oxides of iron and aluminum.
[c] Eleven wells at main pumping station 200 to 1,100 feet deep.
[d] Fourteen wells 800 to 1,000 feet deep; water between 200 and 1,000 feet.
[e] Four wells at electric pumping station, Monroe and Poplar streets, 665 to 975 feet deep.
[f] Depth not given; uncertain whether this is from 400 or 800 foot wells.

The city supply of Bakersfield is taken from shallow wells near Kern River. Madera, Selma, and Visalia also are supplied from wells. Water from Merced River is used in the city of Merced.[1] No analyses of the city supply of Fresno, which is procured from deep wells, are available, but other wells in Fresno and vicinity yield soft or moderately hard calcium carbonate water, clear, tasteless, and entirely acceptable in reference to its mineral content for domestic use. The municipal supply of Los Banos is taken (1910) from an irrigation ditch within the city limits. The water is passed through successive beds of coarse gravel, fine gravel, and charcoal at an excessive rate that precludes proper purification.

MISCELLANEOUS ANALYSES.

ANALYSES BY THE CALIFORNIA EXPERIMENT STATION.

Table 31 has been compiled from reports of the Agricultural Experiment Station of the University of California for 1897–8, 1898–1901 (Part II), 1901–3, and 1903–4, and from "Alkali lands, irrigation, and drainage in their mutual relations," by E. W. Hilgard, an appendix to the report for 1890. The analyses were reported in such form that it is impracticable to resolve them into ionic form for incorporation in other tables of analyses, and they are therefore published in original form, except that the figures have been converted from grains per United States gallon into parts per million. The classification of the waters for irrigation is that reported by the laboratory, and it is not based on the method of interpretation employed by the writer.

As nearly all the examinations are of miscellaneous samples forwarded to the laboratory by persons residing in the valley, data regarding the location of the wells and their depths are necessarily incomplete. It should be understood, therefore, that the first two columns give the name and address of the sender, which do not always coincide with the name of the owner of the well and its location. For example, seven analyses of water from Fresno and six from Hanford are reported, but evidently not all are from wells within the limits of these two cities.

The results of nearly all these examinations accord with the writer's statements regarding the quality of ground waters in the valley. The amount of sulphate, however, represented by the alkaline sulphates reported in the analysis of water from the 1,315-foot well at St. Agnes Academy, Stockton, disagrees with that reported by several chemists in tests of water from other deep wells in and near that city. The discrepancy is doubtless explainable by mixing of samples or error in computation.

[1] Van Winkle, Walton, and Eaton, F. M., The quality of the surface waters of California: U. S. Geol. Survey Water-Supply Paper 237, p. 61, 1910.

TABLE 31.—*Analyses of ground waters in San Joaquin Valley by the Agricultural Experiment Station of the University of California.*

[Parts per million except as otherwise designated.]

San Joaquin County.

Sender.	Address.	Depth of well (feet).	Total solids.	Portion soluble in water after evaporation.	Portion insoluble in water after evaporation.	Organic and volatile matter.	Composition of insoluble portion.		Composition of soluble portion.			Quality for irrigation.
							Silica (SiO_2).	Calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), calcium sulphate ($CaSO_4$).	Alkaline carbonates (Na_2CO_3 + K_2CO_3).	Alkaline chlorides ($NaCl$ + KCl).	Alkaline sulphates (Na_2SO_4 + K_2SO_4).	
R. Hickmott	Bouldin Island	110	1,285	1,005	195	85	35	160	56	928	21	Unsuitable.
Do	do		1,153	898	175	80	45	130	63	730	105	Do.
L. Friedberger	Clements		938	459	215	264	45	170	46	208	205	Doubtful.
Do	do		1,088				Small.	Tr.		High.		Unsuitable.
Do	do	80	299	104	150	45	150		7	11	86	Suitable.
J. D. Ameron	French Camp	200	457	190	192	75	192		7	64	197	Do.
W. H. De Vris	Lodi	20	424					125				Do.
Stockton Asylum	Stockton	1,100	589	436	106	46	54	52	201	235		
Do	do	1,100	626	434	111	80						
Do	do	1,070	819	572	161	86	89	72	153	393	26	
St. Agnes Academy	do	1,315	2,994	2,323	271	400	95	176	53		2,270	
Stockton Water Co.	do	+900	409	197					74	58		
Salmon Estate	French Camp	1,200	4,059	a 3,444	134		54	80		2,125		
Hammond & Yardley	Stockton		600	220	270	110	60	210	44	46	130	Suitable.
J. M. Bigger	do		200								High.	Do.
T. B. Bishop	do		1,535	798	507	230	507		254	467	77	Unsuitable.
A. K. Percival	do	2,000	4,800	4,003	258	539	258					Do.

Stanislaus County.

Sender.	Address.	Depth of well (feet).	Total solids.	Portion soluble in water after evaporation.	Portion insoluble in water after evaporation.	Organic and volatile matter.	Silica (SiO_2).	Calcium carbonate, etc.	Alkaline carbonates.	Alkaline chlorides.	Alkaline sulphates.	Quality for irrigation.
Mrs. J. F. Ecker	Grayson		9,226	6,968	1,647	619	1,647					Unsuitable.
A. Barbour	Newman	100	1,882	1,088	564	230	564		42	752	294	Do.
Do	do	145	1,637	918	519	200	519		32	390	496	Do.
N. O. Hultberg	Turlock		1,015	480	500	35	15	485	128	52	300	Do.
Do	do		1,018	389	509	120	509		17	279	93	Do.

a Calcium chloride, 1,183 parts; magnesium chloride, 297 parts.

TABLE 31.—*Analyses of ground waters in San Joaquin Valley by the Agricultural Experiment Station of the University of California*—Continued.

Sender.	Address.	Depth of well (feet).	Total solids.	Portion soluble in water after evaporation.	Portion insoluble in water after evaporation.	Organic and volatile matter.	Composition of insoluble portion.		Composition of soluble portion.			Quality for irrigation.
							Silica (SiO_2).	Calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), calcium sulphate ($CaSO_4$).	Alkaline carbonates ($Na_2CO_3+K_2CO_3$).	Alkaline chlorides ($NaCl+KCl$).	Alkaline sulphates ($Na_2SO_4+K_2SO_4$).	
Merced County.												
T. Korslab	Dos Palos	....	389	164	190	35	190		15	29	120	Suitable.
H. T. Thornton	Los Banos	....	7,902	....	....	Low.	High.		....	High.	Very high.	Unsuitable.
Madera County.												
A. L. Sayre	Madera	1,200	2,399	1,722	472	205	87	385	34	1,678	10	Unsuitable.
E. C. Foster	do	....	179	57	70	45	70		11	6	40	Suitable.
Fresno County.												
Thomas Akin	Fowler	58	190	70	100	20	20	80	21	12	37	Suitable.
W. E. Price	do	....	379	100	219	60	219		90	6	4	Do.
N. W. Woody	Fresno	....	100	20	50	30	30	20	....	....	20	Do.
H. C. Eggers	do	....	785	495	235	55	108	127	42	153	300	Do.
H. C. McNulty	do	....	333	75	218	40	146	72	11	12	52	Do.
W. H. Hodgkins	do	....	260	50	165	45	40	125	10	12	28	Do.
C. A. Colmore	do	80	224	69	115	40	115		7	29	33	Do.
Barton Vineyard Co	do	....	208	86	108	14	108		17	6	63	Do.
W. Forsaythe	do	....	353	184	120	49	120		21	19	144	Do.
T. Yost	Kingsriver	....	90	....	....	....	....	....	....	....	....	Do.
Geo. E. Bates	do	....	449	199	210	40	210		15	11	173	Do.
Isaac Myers	Mendota	....	8,410	6,688	....	724	....	998	....	....	....	Unsuitable.
W. M. Brown	Sec. 2, T. 14 S., R. 14 E	(a)	1,797	429	1,226	142	51	378	11	274	942	
G. S. Nash	New Idria	....	2,730	2,130	600	....	25	575	10	164	1,956	Unsuitable.
Nellie Russell	Pollasky	....	105	....	....	....	....	....	....	....	....	Suitable.

W. F. Martin	Selma		200							7		Do.
Selma Water Co.	do		101							2		Do.
Do.	do		113							6		Do.
John Hastings	5 miles west of Fresno	105	382	122	156	104						
Kings County.												
S. T. Owings	Armona	30	203	28	162	13	162		8	12	8	Suitable.
Mrs. C. W. Sullivan	do	90	523	316	118	75	118		296	6	14	Doubtful.
S. T. Owings	do	550	289	140	92	57	92		21	24	95	Suitable.
M. W. Motheral	Hanford	40	170	35	120	15	25	95	21	3	11	Do.
C. M. Blowers	do	66	140	30	95	15	95		10	6	14	Do.
J. A. Hill	do	110	2,995	923	1,667	200	1,667					Unsuitable.
Do.	do	150–200	1,118	819	200	99	200		42	29	748	Suitable.
A. V. Taylor	do	900	289	154	90	45	90		85	45	24	Do.
	do	1,150	260	245	10	5	5	5	127	93	25	
E. Jacobs	Lemoore	442	458	368	15	75			330			
Daniel Rhoads	do	900	462	394	13	55			High.			
R. D. Vandeburg	do	164	499	319	100	80	100		211	6	102	Doubtful.
J. H. Hoskins	South of Tulare Lake		133	85	21	27			Low.	High.	High.	
E. Jacobs	Sec. 15, T. 20 S., R. 20 E	660	370	295	41	34	10	31	284		11	
Tulare County.												
W. H. Wilbur	Angiola	80	5,891	3,905	1,587	399		1,587				Unsuitable.
Do.	do	360	3,953	1,967	1,587	399		1,587				Do.
W. T. Rambo	do	16	3,085	1,997	599	489	599					Do.
D. P. Denney	do		1,197	658	429	110	429		278	200	180	Do.
T. Paige	Cross Creek		206	173	33		14	19	153	7	13	
K. A. Linder	Dinuba		210	45	145	20	80	65	11	12	22	Suitable.
	Goshen		165	100	40	25	24	16	74	7	19	
Dr. Pierce	Lindsay		530	190	215	125	75	140	65	47	78	Suitable.
J. H. Williams	Portersville		489	269	130	90	130		69	43	157	Do.
J. W. Williams	do	115	389	279	70	40	40	30	106	46	127	Do.
D. H. Madden	Tulare	220	99	56	26	17	8	18	52		4	
H. Wheeler	do	136	549	484	50	15	15	35	22	116	346	Suitable.
Do.	do		661	541	58	62	20	38	22	11	508	Do.
W. H. Wilbur		360	4,005	2,421	1,255	329	1,255		534	1,473	414	Unsuitable.
Do.		1,100	4,140	2,520	1,060	560	60	1,000	478	1,348	694	Do.
S. F. Hoover	Tulare		155	110	20	25	10	10	64	23	23	Suitable.
W. B. Cartmill			270	50	190	30	190		21	6	23	Do.
E. M. Dewey	7 miles south of Tulare	309	171	89	62	20	35	27			17	
	10 miles north of Visalia	900	1,498	890	194	414				High.		

a Three wells, 380, 414, and 450 feet deep. Analysis reported by owner.

TABLE 31.—*Analyses of ground waters in San Joaquin Valley by the Agricultural Experiment Station of the University of California*—Continued.

Kern County.

Sender.	Address.	Depth of well (feet).	Total solids.	Portion soluble in water after evaporation.	Portion insoluble in water after evaporation.	Organic and volatile matter.	Composition of insoluble portion.		Composition of soluble portion.			Quality for irrigation.
							Silica (SiO_2).	Calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), calcium sulphate ($CaSO_4$).	Alkaline carbonates (Na_2CO_3 $+K_2CO_3$).	Alkaline chlorides ($NaCl+$ KCl).	Alkaline sulphates (Na_2SO_4+ K_2SO_4).	
J. S. Drury	Bakersfield	....	4,425	2,895	1,005	525	45	960	21	12	2,862	Unsuitable.
D. E. Josephi	do	38	4,044	3,308	550	186	65	485	21	255	3,032	Do.
Kern County Land Co.	do	1,000	9,555	9,183	202	170	27	175	1,755	6,385	1,043	Do.
D. E. Josephi	do	....	289	104	145	40	20	125	....	24	80	Suitable.
S. Dickinson	do	....	1,495	1,315	180	....	20	160	22	397	896	Unsuitable.
B. Thomas	Delano	....	353	120	188	45	34	154	16	39	65	Suitable.
J. M. Thompson	Kern	70	179	130	29	20	29		....	....	....	Do.
Do	do	....	211	90	50	71	50		....	....	....	Do.
C. F. Banks	McKittrick	....	5,789	3,593	1,697	499	....	1,697	....	....	....	Unsuitable.
L. S. Harman	Rosedale	....	1,397	419	918	60	918		53	31	285	Do.
	Sec. 33, T. 35 S., R. 23 E.	340	174	86	36	42	....	....	....	....	High.	

ANALYSES BY THE RECLAMATION SERVICE.

A few analyses of water from wells in San Joaquin Valley were made by chemists of the Reclamation Service during 1904 and 1905. Though the results have heretofore been published[1] they are included herewith in order that the analytical records may be complete. The analysis of water from the 1,990-foot well at the State Insane Hospital, Stockton, agrees closely with those of water from other very deep wells in the city. The water of the well at Firebaugh is nearest in composition to that of the 532-foot well at Miller pumping station in sec. 22, T. 13 S., R. 14 E. The highly mineralized water from a flowing well reported as being at Tulare is undoubtedly from a well about 200 feet deep west of Angiola. Though the sources of the other samples can not be identified, the analyses of them agree entirely with the statements made in the preceding text.

TABLE 32.—*Analyses of water from wells in San Joaquin Valley by chemists of the United States Reclamation Service.*

[Parts per million.]

Location.	County.	Date.	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Chlorine (Cl).	Dissolved solids.
State Insane Hospital, Stockton [a]	San Joaquin	Mar., 1907	0	84	3,620	6,940
SE. ¼ sec. 17, T. 11 S., R. 18 E.	Madera	July, 1905	0	174	85	380
NE. ¼ sec. 11, T. 7 S., R. 12 E.	Merced	do	0	123	14	328
SW. ¼ sec. 23, T. 7 S., R. 13 E.	do	do	7	336	70	584
Tulare [b]	Tulare	Dec., 1905	0	1,630	436	2,110
Portersville	do	do	0	205	2	250
Goshen	do	do	3	82	7	156
Firebaugh	Fresno	do	0	195	225	1,420
Buttonwillow	Kern	do	0	455	35	816
Bakersfield	do	do	0	254	21	358
Dudley	Kings	do	0	241	183	2,090

[a] Depth, 1,990 feet; calcium (Ca), 600; magnesium (Mg), 171; sodium and potassium (Na+K), 1,370; sulphate radicle (SO_4), 8 parts per million.
[b] Flowing well.

FORECASTING QUALITY OF GROUND WATER.

The analyses and assays accompanying the county notes (pp. 177–306) are tabulated by range, township, and section, the locations on the Spanish land grants being inserted in proper order to conform to that arrangement. The locations of the wells from which samples of water were collected are indicated in Plate II (in pocket). The tables show first the amounts of the ingredients determined by analysis, then certain computed amounts necessary to proper understanding of the quality, and lastly classifications indicating the approximate nature of the waters and their general usefulness. The information thus tabulated is so detailed that it is not necessary to describe the waters individually in the text. The formulas that

[1] Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, p. 146, 1911.

have been used in the computations and the ratings by which the waters have been classified are fully described in pages 50–83.

The best way to use this material in forecasting the local quality of water is to study the tabulated analyses in connection with Plates II, III, and V and figure 2. After analyses of the water of wells near the locality under consideration have been compared, sections through the locality should be drawn representing the depth of the wells in relation to the composition of their waters. The deeper a well is the greater the area over which its water may be considered representative, because the deep supplies circulate more slowly than the upper ones and are less affected by rainfall, vegetation, and slope. The general direction of movement of the deep waters is from the foothills toward the axis, gradually changing near the axis to a direction parallel with it. Waters within 20 to 50 feet of the surface are diverted more or less from this course by surface configuration—that is, shallow waters move toward near-by gullies, coulees, or watercourses. The somewhat meager information on the subject indicates that shallow wells in the sandy deltas yield better water than shallow wells in the slight depressions between the deltas, and that shallow wells in land showing alkali patches yield poorer water than those in nonalkali tracts. Several shallow wells in dry stream beds were found to yield less strongly mineralized water than neighboring wells not affected by the stream underflow. These conditions are not invariable, but if they are considered with judgment knowledge of them is helpful in predicting the quality of water in the unexplored areas of the valley.

SUMMARY.

The more important conclusions regarding the quality of water in San Joaquin Valley may be summarized as follows:

The waters of the perennial streams are entirely suitable for irrigation; storage to remove suspended matter renders them acceptable for boiler use, and filtration would purify them for domestic supply.

On the east side between the Sierra and the trough of the valley wells 20 to 1,000 feet deep generally yield calcium carbonate waters, moderate in total solids and in total hardness and distinguishable by their low sulphate content. These waters are suitable for domestic use, good or fair for irrigation, and fair or poor for boiler use. Many of them have been successfully applied to diversified crops for several years. Water from wells less than 50 feet deep is generally poorer than that from slightly deeper wells.

On the west side wells between the Coast Range and the trough of the valley yield hard, gypseous waters high in mineral content

and especially in sulphate. Nearly all the waters taste of alkali, but they are potable except the most highly concentrated ones close to the foothills. The west-side waters are poorer for irrigation than those of the east side, but few of them are unfit for use if proper care is taken to prevent accumulation of alkali. They contain so much scale-forming matter that they should be softened before use in boilers, and many of them are so strongly mineralized that they can not be economically softened.

In the axis or trough of the valley wells yield waters distinguishable by the predominance of sodium and potassium among the basic radicles. These waters gradually mingle on either side of the valley with those of the east-side and west-side types, and they are locally altered by seepage from both sides of the valley. The ground waters in the axis differ much from each other in concentration and in composition and therefore in their economic value. Nearly all except the salt waters and those from wells less than 300 feet deep in or near the bed of Tulare Lake are potable. Many of those north of Kings River are poor for irrigation and are too high in foaming constituents to be suitable for steaming. The deep artesian waters south of Kings River are good or fair for irrigation and for boiler use.

Borings more than 1,200 feet deep as far south as Fresno County yield strong salt waters unfit for use, but south of that county wells of that or greater depth, yield sodium carbonate waters of low mineral content. Many flowing wells 300 to 800 feet deep in the axis also yield salt water.

The chief reason for the difference of composition between ground waters of the east and the west side is the different character of the sediments through which they pass; the silt brought down from the Sierra was derived from old, difficultly soluble rocks, but that from the Coast Range was derived from more recent metamorphic and sedimentary rocks containing gypsum and other readily soluble constituents. Alkalines predominate in the axial waters because the more readily soluble constituents have become concentrated during the movement of the waters toward the natural drain of the valley.

The very deep waters of the east side and of the axis increase northward in mineral content, but the shallow waters show no such general relation.

PUMPING TESTS.

By HERMAN STABLER.

NOTES ON THE PLANTS.

During the summer of 1910 pumping tests were made on about 50 irrigation plants in San Joaquin Valley, in connection with other studies of the water supply. In the following pages a description of each plant and test is given, with brief remarks concerning the results shown by the test. The date of installation is given in the heading. The data of chief interest to the irrigator have also been collected in Table 34, in which the various factors in the cost and relative efficiency of the several plants are presented. A summary of the principal points to be observed in order to obtain good service from a pumping plant is also appended.

1. T. R. HILL, LODI, CAL. (1910).

Location.—Lot 7 of the Hogan tract, SW. ¼ sec. 19, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—6-horsepower Samson distillate engine, 18-inch pulley; belt-connected to a 3½-inch Samson horizontal centrifugal pump with 8-inch pulley, catalogue capacity of 250-300 gallons per minute. Well, bored, 8 inches by 44 feet, uncased; water 8 feet below the surface.

Building cost.—Engine, $235; pump, $85; well, $22; complete plant, $385.

Use in 1910.—Preparation of land and irrigation of young alfalfa. Proposed plan of irrigation provides for the watering of 4 acres of alfalfa eight times.

Test.—The following results were obtained during a two-hour test of the plant on September 25, 1910.

Consumption of distillate, gallons per hour, 0.96.

Water pumped, gallons per minute, 256.

Speed, revolutions per minute: Engine, 310 (marked 325); pump, 686 (catalogue speed, 830).

Head: 6-foot lift; 20-foot suction. Total static head, 26 feet.

Remarks.—The plant is about as small as can be satisfactorily used for irrigating alfalfa but is far larger than a 4 or 5 acre alfalfa tract can support. The owner pays a building cost of $96 per acre, and the cost of plant depreciation, maintenance, and operation amounts to $17 per acre annually. At this rate more than half the value of all the alfalfa that can be raised will be required for the upkeep of the pumping plant and payment of taxes and interest and insurance charges. For the first few years this may not be noted by an owner who makes no allowance for depreciation, but as the plant grows older the problem of renewal must be met.

The efficiency of the plant is low. So far as could be noted without detailed study this is accounted for by the following facts: The engine is larger than is required for the work done and is underspeeded and fed an excess of distillate; the pump is much underspeeded. The owner can not hope to make a living on his small tracts by raising alfalfa. His net revenue could be greatly increased by supplying pumped

water to adjacent lands and in such case a 4-inch pump could profitably be installed. Care in designing the plant for proper speeds and in operating would add materially to the owner's success.

2. J. C. DUTTON, LODI, CAL. (1906).

Location.—SW. ¼ sec. 31, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—6-horsepower Samson distillate engine, 22-inch pulley; belt-connected to a 4-inch Samson horizontal centrifugal pump with 8-inch pulley, catalogue capacity 400–450 gallons per minute. Well, bored, 10 inches by 50 to 60 feet, uncased; water 5 to 10 feet below the surface according to season.

Building cost.—Engine, $290; pump, $100; well, $25; complete plant, $495.

Use in 1910.—Irrigation of 3 acres of vineyard watered two or three times, 1 acre of alfalfa, and 1 acre of eucalyptus trees watered once a week or about 12 times in the season.

Test.—The following results were obtained during an hour and a quarter test of the plant on September 26, 1910:

Consumption of distillate, gallons per hour, 1.00

Water pumped, gallons per minute, 380.

Speeds, revolutions per minute: Engine, 248; pump, 666 (catalogue speed, 670).

Head: 6-foot lift; 15-foot suction. Total static head, 21 feet.

Remarks.—The plant is well designed and properly speeded. When tested the batteries were in poor condition and excess of distillate was being used. Poor ignition and relatively low efficiency resulted. The relatively large profits obtainable from a high grade of table grapes probably justify the installation of this plant. The area served is so small, however, that irrigation from it must necessarily be expensive. To provide for economical irrigation by means of this plant an area 10 to 15 times as great should be served with water.

3. J. C. DUTTON, LODI, CAL. (1909?).

Location.—SW. ¼ sec. 31, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—4-horsepower Peerless vertical distillate engine; belt-connected to a 3½-inch Samson horizontal centrifugal pump with 8-inch lagged pulley, catalogue capacity 250–300 gallons per minute. Well, bored, 10 inches by 60 feet, cased for 12 feet; water 14 feet below the surface.

Building cost.—Engine and pump, $325; well, $30; complete plant, $400.

Use in 1910.—Irrigation of 8 acres of vineyard and 2 acres of alfalfa.

Test.—The following results were obtained during a 1¼-hour test of the plant on September 26, 1910:

Consumption of distillate, gallon per hour, 0.75.

Water pumped, gallons per minute, 265.

Speed, revolutions per minute, engine, 310.

Head: 8-foot lift; 19-foot suction. Total static head, 27 feet.

Remarks.—This plant gives results satisfactory in view of its size and irrigation costs that are not unreasonable in consideration of the value of the crops raised. Either plant No. 2 or No. 3, however, if properly located, could do the work of both with much greater economy.

4. A. S. LA SALLE, LODI, CAL. (1902).

Location.—NE. ¼ sec. 25, T. 3 N., R. 6 E., Mount Diablo base and meridian.

Plant.—12-horsepower Hercules distillate engine, 24-inch pulley; belt-connected to a 7-inch Samson horizontal centrifugal pump with 16-inch pulley, catalogue capacity 1,100–1,300 gallons per minute. Wells, three, bored, 8 inches by 90 feet, 10 inches by 90 feet, 17 inches by 90 feet; water 11 feet below the surface.

Building cost.—Engine and pump, $750; complete plant, $1,250.

Use in 1910.—Irrigation of 20 acres of alfalfa four times at the rate of 2 acres in seven hours.

Test.—The following results were obtained during a 2-hour test of the plant on September 27, 1910:

Consumption of distillate: No satisfactory measurement obtainable. Owner states that 12 gallons are required for a 10-hour run, corresponding to 1.2 gallons per hour.

Water pumped, gallons per minute, 868.

Speed, revolutions per minute: Engine, 300; pump, 410 (catalogue speed, 492).

Head: 8-foot lift; 19-foot suction. Total static head, 27 feet.

Remarks.—This plant apparently operates at high efficiency. Records of water pumped and distillate used are both somewhat doubtful, however, so the apparent efficiency may be too high. The engine has been given excellent care and operates in a very satisfactory manner after eight years' use. A 6-inch pump would be better suited to the plant than the one now in use. The 7-inch pump has to be speeded considerably below its economic capacity in order that the engine may not be too heavily overloaded. The owner of this plant has two other pumping plants on his property. One plant properly located could with much greater economy do the work of all three.

5. J. H. HIGH, LODI, CAL.

Location.—Sec. 18, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—Byron Jackson pumping unit, consisting of a 5-horsepower electric motor direct-connected to a 3-inch horizontal centrifugal pump; catalogue capacity, 225 gallons per minute. Well, bored, 8 inches by 25 feet; water 8 feet below the surface.

Building cost.—Pumping unit, $513; well, $16; complete plant, $550.

Use in 1910.—Irrigation of small garden and 2 acres of alfalfa; also, for pumping to elevated tank for domestic use.

Test.—The following results were obtained during a 1-hour test on September 28, 1910:

Current used, kilowatt hours per hour, 4.0.

Water pumped, gallons per minute, 300.

Speed of motor and pump, revolutions per minute, 1,150.

Head: 6-foot lift; 14-foot suction. Total static head, 20 feet.

Remarks.—The efficiency of the plant is low, probably on account of the high speed of the pump necessary for pumping to the elevated tank. The result on the lower lift used for irrigation is overspeeding, increased discharge, and low efficiency. The cost per acre of the plant is far too high to be justified by the value of the crops raised. It is essentially a luxury.

6. P. H. TINDELL, LODI, CAL.

Location.—SW. ¼ sec. 18, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—12-horsepower Fairbanks-Morse distillate engine, 30-inch pulley; belt-connected to a 5-inch Jackson horizontal centrifugal pump with 11½-inch pulley. Catalogue capacity 700 gallons per minute. Well, bored, 8 inches by 150 feet; water 16 feet below the surface; pump installed in 1898, engine in 1906.

Building cost.—Engine, $650; pump, $120; well, $200; complete plant, $1,000.

Use in 1910.—Irrigation of 5 acres of alfalfa six times, 13.5 acres of vineyard once, 28.5 acres of vineyard twice, and 10 acres of vineyard three times. Two to two-and-a-half acres irrigated per day of 12 hours.

Test.—The following results were obtained during a one-hour-test on September 28, 1910:

Consumption of distillate, gallons per hour (from owner's record, no measurement being obtainable), 1.20.

Water pumped, gallons per minute, 605.

Speed, revolutions per minute: Engine, 263; pump, 645.

Head: 11-foot lift; 20-foot suction. Total static head, 31 feet.

Remarks.—This plant, being operated with fair efficiency to irrigate 52 acres, is subject to the reasonable water cost of $3.60 per acre per year or $2.60 per acre-foot of water pumped. The crops raised can readily stand such a charge. The amount of water used, 1.4 acre-feet per acre per year, is rather low because of the relatively small water requirement of vineyards. The plant is of sufficient capacity to irrigate an area fully twice as great as that now watered from it.

7. GEORGE D. KETTLEMAN, LODI, CAL. (1910).

Location.—SW. ¼ sec. 7, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—20-horsepower Samson distillate engine, 30-inch pulley; belt-connected to a 6-inch Samson horizontal centrifugal pump with 12-inch pulley, catalogue capacity 800–1,000 gallons per minute. Well, bored, 12 inches by 46 feet, uncased; water 18 feet below the surface. Engine house has substantial cement floor and very heavy concrete engine base.

Building cost.—Engine, $760; pump, $90; well, $30; complete plant, $1,200.

Use in 1910.—Irrigation of 4 acres of alfalfa 10 times at the rate of 0.4 to 0.3 acre per hour. Also as insurance against drought for a large vineyard, though no irrigating water was supplied to the vineyard lands.

Test.—The following results were obtained during a 4-hour test of the plant on September 29, 1910:

Consumption of distillate, gallons per hour, 1.83.

Water pumped, gallons per minute, 914.

Speed, revolutions per minute: Engine, 222; pump, 530 (catalogue speed, 566).

Head: 8-foot lift; 20-foot suction. Total static head, 28 feet.

Remarks.—This plant is remarkable on account of the very high yield of the well, 0.204 second-foot per foot of draw-down. Except for wells in a stream bed, no other well tested in San Joaquin Valley was found to have a capacity 85 per cent as great. A considerable amount of sand has been pumped out and on account of the heavy draft some sand continues in the discharge. The cost of operation in 1910 was $31 per acre irrigated, a very large proportion of the value of the alfalfa raised. The building of such a large plant can not be justified by the use to which it is put. The insurance against drought for the vineyard is perhaps its greatest value. In any case a considerably smaller plant would be fully as useful and much less expensive than the one installed. Only fair efficiency is obtained, the pump being slightly underspeeded and the engine working at small load.

8. CHARLES RASH, LODI, CAL. (1909).

Location.—NW. ¼ sec. 19, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—10-horsepower Samson distillate engine; 20-inch pulley; belt-connected to a 5-inch Samson horizontal centrifugal pump with 10-inch pulley; catalogue capacity, 600–700 gallons per minute. Well, bored, 12 inches by 48 feet, uncased.

Building cost.—Engine, $350; pump, $75; well, $30; complete plant, $550.

Use in 1910.—Irrigation of 2.5 acres of alfalfa six times. Available for use in vineyard also.

Test.—The following results were obtained during a two-hour test of the plant on September 30, 1910:

Consumption of distillate, gallons per hour, 1.50.

Water pumped, gallons per minute, 406.

Speed, revolutions per minute: Engine, 303; pump, 596 (catalogue speed, 646).

Head: 3-foot lift; 23-foot suction. Total static head, 26 feet.

Remarks.—The plant is well designed in most respects. The pump should be set lower, however, in order to avoid excessive suction lift. The operating efficiency

was very low during the test. This was due in part to excessive feeding of distillate and in part to the presence of air in the pump. The pump was also somewhat underspeeded. In order to secure reasonable economy, the plant should serve a much greater acreage. As used in 1910, the building cost of the plant is $220 per acre irrigated and the annual cost of irrigation $32 per acre, or $7.80 per acre-foot of water pumped. The crops raised are not of sufficient value to warrant such irrigation costs.

9. JOHN TRETHEWAY, LODI, CAL. (1908).

Location.—NW. ¼ sec. 11, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—25-horsepower Samson distillate engine; 32-inch pulley; belt-connected to a 7-inch Samson horizontal centrifugal pump with 14-inch pulley (catalogue capacity, 1,100–1,300 gallons per minute). Well, bored, 13 to 8 inches by 137 feet, cased; water 26 feet below the surface.

Building cost.—Engine, $900; pump, $120; well, $100; complete plant, $1,300.

Use in 1910.—Irrigation of garden and of 14 acres of alfalfa, watered twice.

Test.—The following results were obtained during a two-hour test of the plant on October 3, 1910:

Consumption of distillate, gallons per hour, 1.57.

Water pumped, gallons per minute, 425.

Speed, revolutions per minute: Engine, 220; pump, 460 (catalogue speed, 630).

Head: 22-foot lift; 26-foot suction. Total static head, 48 feet.

Remarks.—The operation efficiency of this plant was excellent when all conditions are considered, though the actual results were poor. The engine and pump were underspeeded in order that the capacity of the well might not be exceeded, and the distillate feed choked as far as practicable. A much smaller plant would pump with better efficiency all the water that the well can supply. More extended irrigation from this plant is proposed, but additional water supply from additional wells or from reconstruction of the present well will be necessary to make the plant a success.

10. J. A. HIEB, LODI, CAL. (1907).

Location.—SW. ¼ sec. 15, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—8-horsepower Fairbanks-Morse distillate engine, 24-inch pulley; belt-connected to a 4-inch Samson horizontal centrifugal pump with 8-inch lagged pulley; catalogue capacity, 400–450 gallons per minute. Well, bored, 8 inches by 46 feet, uncased; water 19 feet below the surface.

Building cost.—Engine, $470; pump, $70; well, $25; complete plant, $650.

Use in 1910.—Irrigation of 4 acres of alfalfa, watered 18 times, at the rate of one-third of an acre per hour.

Test.—The following results were obtained during a one-hour test of the plant on October 4, 1910:

Consumption of distillate, gallons per hour (owner's statement of average requirement, no satisfactory measurement being obtainable), 1.00.

Water pumped, gallons per minute, 444.

Speed, revolutions per minute: Engine, 275 (118 explosions); pump, 750 (catalogue speed, 743).

Head: 7-foot lift; 20-foot suction; total static head, 27 feet.

Remarks.—This plant is well designed, the various parts being well adapted to one another. The efficiency appears to be lower than would be expected, but this is probably due to the rather heavy draft of distillate. The building cost and operation and maintenance costs per acre of land irrigated are unreasonably high in view of the crops raised, for the plant is of sufficient size to irrigate an area twenty times as great as that for which it is actually utilized.

11. SAM KUMMIS, LODI, CAL.

Location.—SE. ¼ sec. 24, T. 3 N., R. 6 E., Mount Diablo base and meridian.

Plant.—12-horsepower distillate engine (unknown make), 36-inch pulley; belt-connected to a 6-inch Samson horizontal centrifugal pump with 12-inch lagged pulley; catalogue capacity, 800–1,000 gallons per minute. Engine and pump on a portable platform and used to pump from three wells located at convenient points; water about 9 feet below the surface.

Estimated building cost.—Engine, $600; pump, $105; wells, $150; complete plant, $900.

Use in 1910.—Irrigation of 60 acres of almonds and alfalfa, mostly almonds.

Test.—The following results were obtained during a short test on October 4, 1910:

Consumption of distillate, gallons per hour (owner's statement of average use, no measurement being obtainable), 1.20.

Water pumped, gallons per minute, 444.

Speed, revolutions per minute: Engine, 138; pump, 400 (catalogue speed, 566).

Head: 3-foot lift; 24-foot suction; total static head, 27 feet.

Remarks.—The engine is an old one but is still doing good service. The plant operates at low efficiency, chiefly because the speed is very low, this being necessary in order to avoid excessive suction lift. A portable centrifugal pump can be used to advantage only in case the water table is close to the surface of the ground. An 8-horsepower engine and a 4-inch pump would do the work of this plant with greater efficiency and at about two-thirds the building cost.

12. W. G. MICKE, LODI, CAL. (1905).

Location.—NW. ¼ sec. 7, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—Byron Jackson pumping unit, consisting of a 3-horsepower electric motor direct-connected to a 2-inch horizontal centrifugal pump, catalogue capacity, 100 gallons per minute. Well, bored, 5 inches in diameter, shallow; water 16 feet below the surface.

Building cost.—About $250 for the completed plant.

Use in 1910.—Irrigation of 1.5 acres of alfalfa and garden five times at the rate of 0.06 acre per hour.

Test.—The following results were obtained during a 2-hour test of the plant on October 6, 1910.

Current used, kilowatt-hours per hour, 2.0.

Water pumped, gallons per minute, 108.

Speed of motor and pump, revolutions per minute, 1,700.

Head: 6-foot lift; 19-foot suction. Total static head, 25 feet.

Remarks.—This plant has low efficiency because of its small size. As it lies idle the greater portion of the time, the costs per acre are large even though the current is purchased on the basis of actual use.

13. MRS. WM. P. BEARD, LODI, CAL. (1910).

Location.—NW. ¼ sec. 30, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—5-horsepower Samson distillate engine, 20-inch pulley; belt-connected to a 3½-inch Samson horizontal centrifugal pump with 7-inch pulley, catalogue capacity, 250–300 gallons per minute. Well, bored, 8 inches by 50 feet, uncased; water 12 feet below the surface.

Building cost.—Engine, $200; pump, $85; well, $4; complete plant, $325.

Use in 1910.—Irrigation of 2 acres of alfalfa and 0.3 acre of garden six times.

Test.—The following results were obtained during an hour-and-a-half test on October 6, 1910.

Consumption of distillate, gallon per hour, 0.80.

Water pumped, gallons per minute, 249.

Speed, revolutions per minute: Engine, 276; pump, 716 (catalogue speed, 807).

Head: 5-foot lift, 19-foot suction. Total static head, 24 feet.

Remarks.—This plant is operated at low efficiency on account of small size, low speed of pump, and slip of belt. The area irrigated is so small that the building cost per acre and cost per acre of operation and maintenance are excessive.

14. JACOB WAGNER (1904).

Location.—NW. ¼ sec. 19, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—12-horsepower Fairbanks-Morse distillate engine, 28-inch pulley; belt-connected to a 5-inch Krogh "Pacific" horizontal centrifugal pump with 10-inch pulley, catalogue capacity, 500 to 950 gallons per minute. Well, bored, 12 inches by 115 feet, cased; water 14 feet below the surface.

Building cost.—Complete plant estimated at $1,000.

Use in 1910.—Irrigation of 6 acres of alfalfa watered five times at the rate of 0.07 acre per hour.

Test.—The following results were obtained during a 2-hour test on October 7, 1910.

Consumption of distillate, gallons per hour, 1.25.

Water pumped, gallons per minute, 299.

Speed, revolutions per minute: Engine, 232 (118 explosions); pump, calculated, 650 (catalogue speed, 573).

Head: 11-foot lift; 24-foot suction. Total static head, 35 feet.

Remarks.—As is the case with most plants on which tests were made in this neighborhood, the costs are high by reason of the small area of irrigation. The efficiency of this plant is very low and can not be explained by reasons that were apparent. The discharge is far too small for size and speed of the pump, and there were indications of air leakage in the suction pipe. It may be, however, that poor condition of the pump or clogging of the foot valve is the cause of the low efficiency. The well is deeper than most in the vicinity, and the upper aquifers are cased off. This seems to have been a mistake in construction, as the capacity of the well is relatively small.

15. W. E. BUNKER, GUSTINE, CAL. (1910).

Location.—NW. ¼ sec. 7, T. 9 S., R. 9 E., Mount Diablo base and meridian.

Plant.—100-horsepower Samson four-cylinder vertical distillate engine; direct-connected to a 26-inch Samson horizontal centrifugal pump, catalogue capacity 16,000 gallons per minute.

Building cost.—Engine, $2,850; complete plant, $3,950.

Use.—Pumping for irrigation from a gravity canal through 8-foot suction and 12-foot lift (total static head 20 feet) to high lands. In 1910 156 acres of raw land was watered once at the rate of 0.64 acre per hour using 7.5 gallons of distillate per hour. Plan of irrigation provides for watering 350 acres of alfalfa twice per season.

Remarks.—Though not an underground water development, this plant, which was visited but not tested, is cited as an example of a type of plant being installed at various localities on the west side of San Joaquin Valley in a region highly developed for alfalfa and dairying. The land is reputed to be salable at $30 per acre without and $300 per acre with a water right. Plants of this type extend the use of flood waters to high lands that could not otherwise be watered. Water is supplied by the canals only until sometime in July or August so that the growing season is relatively short. Plants that can quickly irrigate a large area seem to be essential in view of the conditions and the value of the crops seems to warrant rather high costs. From the use of distillate and time for watering it is evident that the plant was not operated at full capacity in 1910.

16. JOE HOUSE, GUSTINE, CAL. (1909).

Location.—SW. ¼ sec. 6, T. 8 S., R. 9 E., Mount Diablo base and meridian.

Plant.—25-horsepower Samson distillate engine; 14-inch Samson centrifugal pump, catalogue capacity 5,000 to 6,000 gallons per minute.

Building cost.—Engine, $900; complete plant, $1,500.

Use in 1910.—Irrigation of 77 acres of alfalfa twice at the rate of 1.15 acres per hour.

Remarks.—This plant receives its water supply from a gravity canal. The pump operates under water and has a lift of 5.5 feet to 14 acres and 3.5 feet to 63 acres of land. The costs for the season were $19 for distillate at 10 cents a gallon, $1 for lubricating oil, and a merely nominal amount for attendance. The water supply is usually available until some time in July or August. The plant was visited on October 11 but no tests were made. From the foregoing data, supplied by the owner, the efficiency is excellent and the total cost of irrigation about $2.90 per acre. To this should be added $1.50 to $3 per acre charged by the gravity canal company for the water supplied.

17. PATTERSON COLONY, PATTERSON, CAL. (1910).[1]

This plant is located near the new town of Patterson on the west bank of San Joaquin River about 30 miles southwest of Stockton. It is noteworthy as being the largest irrigation pumping plant in San Joaquin Valley. The Rancho del Puerto, or Patterson Ranch, containing about 18,000 acres of land, has been subdivided and is being sold in small holdings with a water right providing for irrigation of the lands with water pumped from San Joaquin River. The irrigable area contains about 14,000 acres and is watered with an assumed duty of water of 1 second-foot to 160 acres from five sections of main canal differing about 13 feet in elevation. The main pumping plant with a capacity of 50,000 gallons per minute (111 second-feet) is located on the river bank and raises the water about 21 feet to the first-lift canal. The first-lift canal supplies water to a large area of land and terminates in a small reservoir supplying a second pumping station that raises water to the second lift canal. The second-lift canal, in turn, supplies water to the land and through a reservoir to a third pumping station. In the same way the fourth and fifth pumping stations and the third, fourth, and fifth lift canals are operated. The canals and reservoirs are lined with concrete and extend about 17,500 feet in a straight line west from the river. The motive power is electricity supplied 19 hours a day (to avoid peak load) at the low rate of three-fourths of a cent per kilowatt-hour actually used. The pumps are of the horizontal centrifugal type, were specially designed for the conditions under which they operate, and gave efficiencies over 75 per cent in tests at the factory. The pump equipment planned for the several stations (about half installed in 1910) is as follows:

TABLE 33.—*Pumping equipment, Patterson colony.*

Station.	Number and size of pumps.	Station capacity in gallons per minute.	Accumulated lift in feet.
1	Four 20-inch	50,000	21
2	Three 20-inch; one 18-inch	46,000	34
3	Two 20-inch; one 15-inch	31,000	47
4	Three 15-inch	18,000	60
5	One 15-inch	6,000	73

[1] The construction of this pumping system has been described in detail by G. C. Stevens (Eng. Record, vol. 62, pp. 284–286, 1910).

18. P. ALLING, LODI, CAL. (1908).

Location.—NE. ¼ sec. 30, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—5-horsepower Samson distillate engine, 17-inch pulley; belt-connected to a 4-inch Samson horizontal centrifugal pump with 8-inch lagged pulley, catalogue capacity 400–450 gallons per minute. Well, bored, 6 inches by 46 feet, uncased; water 11 feet beneath the surface.

Building cost.—Engine, $200; pump, $70; well, $25; complete plant, $355.

Use in 1910.—Irrigation of 3.5 acres of alfalfa and a small area of eucalyptus trees and garden eight times at the rate of 0.12 acre per hour.

Test.—The following results were obtained during a 2-hour test on October 13, 1910.

Consumption of distillate, gallons per hour, 0.97.

Water pumped, gallons per minute, 406.

Speed, revolutions per minute: Engine, 328; pump, 642 (catalogue speed, 694).

Head: 7-foot lift; 16-foot suction. Total static head, 23 feet.

Remarks.—The well at this plant has very great capacity for one of so small a diameter. The efficiency of the plant is low and is accounted for by the use of an excess of distillate. The unit costs are high on account of the small area irrigated. The plant is well kept, and with more extensive irrigation operations would give excellent results.

19 AND 20. HOGAN BROS., LODI, CAL. (1904).

Location.—SW. ¼ sec. 19, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—12-horsepower Fairbanks-Morse distillate engine, 22-inch pulley; belt-connected to a 5-inch Krogh "Pacific" horizontal centrifugal pump with 10-inch pulley, catalogue capacity 500–950 gallons per minute. Well, bored, 12 inches by 46 feet, uncased; water 9 feet below the surface.

Building cost.—Complete plant, $1,000.

Use in 1910.—In conjunction with plant No. 21, for the irrigation of 30 acres of alfalfa, 5 acres of strawberries, and 5 acres of garden truck.

Tests.—The following results were obtained from a 1.5-hour test of the plant on October 5, 1910, and a 2-hour test on October 14, 1910, respectively.

Consumption of distillate, gallons per hour, 1.67–2.12.

Water pumped, gallons per minute, 710–640.

Speed, revolutions per minute: Engine, 267–271 (117–124 explosions); pump, 557–577 (catalogue speed, 524).

Head: 3.5-foot lift; 24.5-foot suction. Total static head, 28 feet.

Remarks.—The engine is an old one. The cylinder has been rebored and at the time of the test needed repacking as it allowed considerable escape of gases. An excess of distillate was being used. The efficiency of the plant was low, but the unit costs are better than for many neighboring plants because a larger relative area is irrigated.

21. HOGAN BROS., LODI, CAL. (1909).

Location.—SW. ¼ sec. 19, T. 3 N., R. 7 E., Mount Diablo base and meridian.

Plant.—12-horsepower Union vertical distillate engine, 18-inch pulley; belt-connected to a 5-inch Globe horizontal centrifugal pump with 14-inch pulley. Well, bored, 12 to 6 inches by 55 feet, cased 25 feet; water 12 feet below the surface.

Building cost.—Complete plant, $1,000.

Use in 1910.—In conjunction with plant No. 20, for the irrigation of 30 acres of alfalfa, 5 acres of strawberries and 5 acres of garden truck.

Test.—The following results were obtained during a 1.5-hour test of the plant on October 14, 1910.

Consumption of distillate, gallons per hour, 1.38.

Water pumped, gallons per minute, 500.

Speed, revolutions per minute: Engine, 343; pump, 427.

Head: 2-foot lift; 25-foot suction. Total static head, 27 feet.

Remarks.—This plant is operating at low efficiency. This is probably due in part to the great suction lift approaching the limit of practicable operation, and in part to the low speed of the pump. The economic discharge and speed of pump are not known, but it is probably considerably underspeeded and working at low efficiency to develop a relatively small discharge.

22. E. P. TYLER (1910).

Location.—Lot 233, Merced Colony; NE. ¼ sec. 5, T. 8 S., R. 14 E., Mount Diablo base and meridian.

Plant.—35-horsepower General Electric Co. induction motor, 9½-inch pulley; belt-connected to a 10-inch Jackson horizontal centrifugal pump with 21-inch pulley, catalogue capacity, 3,000 gallons per minute. Wells, bored, one 12 to 10 inches by 172 feet, one 12 to 8 inches by 292 feet, one 12 to 8 inches by 220 feet, all cased 40 to 50 feet; water 6 feet below the surface.

Building cost.—Wells, $680; house, $150; installation, $220; pump, motor, and transformers, $1,950; complete plant, $3,000.

Use in 1910.—Irrigation of 4 acres of alfalfa and as demonstration pumping plant for Merced Colony. Will be used to irrigate all crops on a ranch of 174 acres.

Test.—The following results were obtained during a test of the plant on October 18, 1910.

Current used, kilowatt-hours per hour, 28 (owner's record for season).

Water pumped, gallons per minute, 2,160.

Speed, revolutions per minute: Motor, 1,160; pump, 550 (catalogue speed, 550).

Head: 5-foot lift; 23-foot suction. Total static head, 28 feet.

Remarks.—This plant operates with only fair efficiency, and though the pump is apparently speeded properly the discharge is far below the catalogue capacity. There were some indications of air leakage in the suction pipe, but the cause of the poor results was not ascertained with certainty. Electric current was obtained at the rate of 3 cents per kilowatt-hour delivered. The plant costs were high in 1910, but with increase in area irrigated as proposed will be reduced to reasonable amounts.

23. W. R. GIRARD, MERCED, CAL. (1910).

Location.—Lot 185, Merced Colony; SW. ¼ sec. 32, T. 7 S., R. 14 E., Mount Diablo base and meridian.

Plant.—10-horsepower General Electric Co. induction motor, 8½-inch pulley; belt-connected to a 5-inch Samson horizontal centrifugal pump with 14-inch pulley; catalogue capacity 600–700 gallons per minute. Well, bored, 12 inches by 235 feet, cased for about 50 feet; water 6 feet below the surface.

Building cost.—Transformers, $131; motor, $209; pump and accessories, including digging pit and installing pump and motor, $206; building, $50; well and casing, $174; miscellaneous supplies and labor, $38; complete plant, $808.

Use in 1910.—Irrigation of 18 acres of alfalfa.

Test.—The following results were obtained during a 1-hour test of the plant on October 18, 1910.

Current used, kilowatt-hours per hour, 8.6.

Water pumped, gallons per minute, 630.

Speed, revolutions per minute: Motor, 1,160; pump, 700 (catalogue speed, 581).

Head: 3.5-foot lift; 16.5-foot suction. Total static head, 20 feet.

Remarks.—This plant was in good condition when tested. The pump is apparently slightly overspeeded but no reason for appreciable lack of efficiency was apparent. Nevertheless the recorded efficiency was very low. The record of current used, however, was taken from a meter reading without other tests and is probably too high. A meter reading of about 6 kilowatt-hours would have indicated a satisfactory efficiency.

24. S. M. PATE, MERCED, CAL. (1905).

Location.—NW. ¼ sec. 21, T. 8 S., R. 13 E., Mount Diablo base and meridian.

Plant.—15-horsepower Samson distillate engine, 28-inch pulley; belt-connected to a 6-inch Samson horizontal centrifugal pump with 12-inch pulley, catalogue capacity 800–1,000 gallons per minute. Well, bored, 12 inches in diameter; water 15 feet below the surface.

Building cost.—Complete plant, estimated, $760.

Use in 1910.—Irrigation of several acres of alfalfa.

Test.—The following results were obtained during a test of the plant on October 19, 1910.

Water pumped, gallons per minute, 765.

Speed, revolutions per minute: Engine, 231; pump, 547 (catalogue speed, 592).

Head: 9-foot lift; 21-foot suction. Total static head, 30 feet.

Remarks.—No measurement or owner's record of use of distillate could be obtained. The pump is slightly underspeeded and operates below economical capacity.

25. JESSE RODERIGS, MERCED, CAL. (1907).

Location.—NW. ¼ sec. 10, T. 7 S., R. 13 E., Mount Diablo base and meridian.

Plant.—12-horsepower Samson distillate engine, 24-inch pulley; belt-connected to a 6-inch Samson horizontal centrifugal pump with 12-inch pulley, catalogue capacity 800 to 1,000 gallons per minute. Well, bored, 10 to 7 inches by 84 feet, cased 71 feet; water 9 feet below the surface.

Building cost.—Well and casing, $68; building, $66; complete plant, $700.

Use in 1910.—Irrigation of 9 acres of grapes once, 16 acres of sweet potatoes once a week, and 3 acres of alfalfa five times.

Test.—The following results were obtained during a 1.5-hour test of the plant on October 20, 1910.

Consumption of distillate, gallons per hour, 1.61.

Water pumped, gallons per minute, 400.

Speed, revolutions per minute: Engine, 232; pump, 460 (catalogue speed, 575).

Head: 8-foot lift; 20-foot suction. Total static head, 28 feet.

Remarks.—During the latter part of the test the engine was speeded up to 256 revolutions per minute and the discharge increased to 450 gallons per minute with 4 feet additional draw down. The speed regulator on the engine was worn so that normal speed could not be maintained, the extra speed during the latter part of the test being secured by a temporary makeshift.

Though the pump is underspeeded it is apparently not producing the discharge that it should and probably needs careful overhauling. The engine is using an excess of distillate and leaks badly around the piston. The efficiency is low. The plant is too large for the owner's use as he states that the discharge is as great as he can take care of to advantage. An 8-horsepower engine and a 4-inch pump would be a much more suitable and economical installation for this plant.

26. A. L. SAYRE, MADERA, CAL.

Location.—SE. ¼ sec. 31, T. 11 S., R. 18 E., Mount Diablo base and meridian.

Plant.—50-horsepower electric motor, 16-inch pulley; belt-connected to a 10-inch Jackson horizontal centrifugal pump with 14-inch pulley, catalogue capacity 3,900 gallons per minute. Three wells, bored, 10 to 12 inches by 110 feet, uncased; water 19 feet below the general surface; pump installed in 1903; electric machinery in 1909.

Building cost.—Transformers, $660; motor, $550; wiring, etc., $150; pump, about $550; complete plant, $3,000. A gas producer and gas engine costing $2,800 formerly operated the plant but have been discarded for electric machinery.

Use in 1910.—Irrigation of 225 acres of vineyard once, and 450 acres of alfalfa five times, and 55 acres of hay and sorghum twice. Operated almost continuously from March or April to October.

Test.—The following results were obtained during a 3.5-hour test of the plant on October 21, supplemented by a brief test on October 23, 1910.

Current used: 36.6 kilowatt-hours per hour by meter measurement, equivalent to 49.0 horsepower.

Water pumped, gallons per minute, 2,300.

Speed, revolutions per minute: Motor, 689; pump, 800 (catalogue speed, 650).

Head: 19.5-foot lift; 21.5-foot suction. Total static head, 41 feet. Suction head by gage, 22.5 inches of mercury or 25.5 feet; hence total head including friction is about 45 feet.

Remarks.—After the test on October 21 the owner protested that the measurement of water must be in error. Accordingly a second measurement was made on October 23 with essentially the same result. Every precaution was taken to insure accurate results, and there can be no serious doubt of the recorded flow. The pump is operated at excessive speed and should under these conditions give a discharge of more than 3,000 gallons per minute, but presumably on account of wear and great suction lift the actual discharge does not exceed 2,300 gallons per minute. As the plant is operated almost continuously throughout the irrigation season to water a large area the unit costs are low. The water-right charge or building cost amount to only $7.50 per acre and the cost of operation and maintenance, including depreciation, renewals, and repairs, amounts to only $3.60 per acre, or $1.50 per acre-foot of water pumped. Irrigation can scarcely fail to be profitable on such terms even with crops of relatively small value.

This plant had a larger discharge than any other tested and was so operated as to give irrigation costs that could be compared favorably with those of any other plant in the valley working under similar conditions as to head and rate charged for power.

27. H. W. PATTERSON, BORDEN, CAL.

Location.—SW. ¼ sec. 8, T. 12 S., R. 18 E., Mount Diablo base and meridian.

Plant.—42-horsepower steam traction engine, 40.5-inch pulley; belt-connected to an 8-inch Jackson horizontal centrifugal pump with 15.5-inch pulley, catalogue capacity, 1,600 gallons per minute. Wells, bored, 10 inches by 96 feet and 10 inches by 134 feet; water 22 feet below the surface. Reservoir with earth embankments and capacity of about 1,000,000 gallons, used to collect water pumped at night; pump installed in 1904; engine purchased in 1909.

Building cost.—Complete plant, $3,500.

Use in 1910.—Irrigation of 30 acres of orchard twice, 50 acres of alfalfa four times, and 40 acres of corn and barley once.

Test.—The following results were obtained during a test of the plant on October 24, 1910.

Consumption of crude oil, gallons per hour, 14.00 (owner's record from test run of 15.5 hours).

Water pumped, gallons per minute, 1,320.

Speed, revolutions per minute: Engine, 229; pump, 588 (catalogue speed, 695).

Head: 19.5-foot lift, 20.5-foot suction (19 inches by gage). Total static head, 41 feet.

Remarks.—This is one of the few steam pumping plants remaining in the valley and the only one tested. The costs are not materially different from those for distillate or electric plants under similar conditions, but the additional attention required in the operation of a steam plant is responsible for its general unpopularity.

The pump is underspeeded and produces a relatively low discharge.

28. S. W. SKAGGS, BORDEN, CAL. (1907-8).

Location.—SE. ¼ sec. 6, T. 12 S., R. 18 E., Mount Diablo base and meridian.

Plant.—30-horsepower Samson distillate engine, 46-inch pulley; belt-connected to a 6-inch Price horizontal centrifugal pump with 10-inch pulley. Wells, bored, 112 and 186 feet in depth, cased; water 14 to 18 feet below the surface.

Building cost.—Complete plant, $3,200.

Use in 1910.—Irrigation of 60 acres of alfalfa three times. (First two waterings in season given from gravity supply.)

Test.—The following results were obtained during a 2-hour test of the plant on October 24, 1912.

Consumption of distillate, gallons per hour, 3.8.

Water pumped, gallons per minute, 780.

Speed, revolutions per minute: Engine, 204; pump, 905.

Head: 16-foot lift, 25.5-foot suction (by gage). Total static head about 42 feet.

Remarks.—The engine was using an excessive amount of distillate and the efficiency is in consequence low. Great suction lift probably also contributes to the low efficiency. The building and operation and maintenance costs are reasonable.

29. WALTERS BROS., MADERA, CAL. (1903).

Location.—Sec. 32, T. 11 S., R. 18 E., Mount Diablo base and meridian.

Plant.—45-horsepower Hercules distillate engine, 70.5-inch pulley; belt-connected to a 7-inch California (Krogh) horizontal centrifugal pump with 20-inch pulley. Wells, bored, 10 inches by 104 feet, cased, and 10 inches by 174 feet, cased to 134 feet; water 22 feet below the surface.

Building cost.—Complete plant, $3,500, including $500 for pump pit.

Use in 1910.—Irrigation of 50 acres of alfalfa four times; 35 acres of vineyard once, and 15 acres of hay and barley twice, at the rate of 0.35 acre per hour.

Test.—The following results were obtained during a test of the plant on October 25, 1910.

Consumption of distillate, gallons per hour: 4.00 (from owner's statement, no accurate measurement being obtainable).

Water pumped, gallons per minute, 1,900.

Speed, revolution per minute: Engine, 162; pump, 565.

Head: Lift, 21 feet; suction, 25.5 feet (by gage). Total static head about 46 feet.

Remarks.—The efficiency of this plant appears to be very high but both use of distillate and discharge are open to question. The plant is well operated and gives good results as to cost when the head is considered.

30. VALLE-VERDE INVESTMENT CO., FRESNO, CAL. (1909).

Location.—Near Mendota, Cal., in sec. 2, T. 14 S., R. 14 E., Mount Diablo base and meridian.

Plant.—75-horsepower Samson vertical 3-cylinder distillate engine, 40-inch pulley; belt-connected to an 8-inch Jackson double-suction vertical centrifugal pump with 13-inch pulley; catalogue capacity, 1,600 gallons per minute. Wells, bored, 12 inches by 380 feet and 450 feet, cased and 80 feet of casing perforated; 9.6 inches by 414 feet, cased and 80 feet of casing perforated and wrapped spirally with wire of triangular cross section; water 52 feet below the surface.

Building cost.—Complete plant, $6,500, including $1,500 for the two 12-inch wells and $1,800 for the third well.

Use in 1910.—Irrigation of 2 acres of alfalfa eight times, 6 acres of broom corn twice, 40 acres of Egyptian corn twice, 10 acres of Kaffir corn three times, and a half acre of garden twelve times.

Test.—The following results were obtained during a test of the plant on October 27, 1910.

Consumption of distillate, gallons per hour, 7.27.

Water pumped, gallons per minute, 1,080.

Head: 51-foot lift; 31-foot suction (by gage). Total static head about 82 feet.

Remarks.—This plant is the only one on the "west side" that was tested. The depth to water is over 50 feet and the flow of water, occurring in fine sand, is not free. The two wells without special casing give a comparatively small flow because of clogging with sand. The third well gives much better results, being fitted with a special screen such as is described by Bowman.[1] After all, however, the suction head is excessive and accounts for the fairly low efficiency of the plant and the small discharge of the pump.

The building cost of the plant is about $34 per acre of land that it will irrigate, though with the small area now watered the cost is over $100 per acre. The cost of operation and maintenance is now about $8.40 per acre-foot of water pumped but could be reduced to $4.10 per acre-foot if operated for the irrigation of a larger area. The costs, even under the best conditions, must be a relatively high proportion of the value of ordinary crops raised and every care should be taken to secure economy in the operation of such a plant if it is to be used successfully.

31. ROSEDALE WATER CO., PORTERSVILLE, CAL. (1897).

Location.—Sec. 3, T. 22 S., R. 28 E., Mount Diablo base and meridian.

Plant.—20-horsepower Westinghouse induction motor; direct-connected to a 4-inch California (Krogh) horizontal centrifugal pump. Wells located adjacent to and on both sides of Tule River as follows: Dug well 28 feet deep; bored well 12 inches by 35 feet; shaft or dug well 18 feet deep. Wells connected by tunnel or piping.

Building cost.—Complete plant estimated, $1,300, not including extensive system for water delivery.

Use in 1910.—Operated continuously from April to October 15 for four and five waterings of 22 citrus orchards aggregating 177 acres in area.

Test.—The following results were obtained during a test of the plant on November 3, 1910.

Current used, horsepower, 23.00 (from power company's bill), equivalent to 17.15 kilowatt-hours per hour.

Water pumped, gallons per minute, 565.

Speed, of motor and pump, revolutions per minute, 1,125.

Head: 74-foot lift; 5-foot suction. Total static head, 79 feet.

Remarks.—This plant is owned and operated in cooperation by 22 orchardists. Each pays to the cooperative organization 50 cents per hour for the time that water is supplied by the plant to his lands. In this manner all receive irrigation water much more economically than if each owned a plant for his own exclusive use. Being operated continuously throughout the irrigation season the cost of pumping water amounts to less than $2.50 per acre-foot even though the head is 79 feet. The wells are located on the edge of Tule River and generally give a full supply of water with little drawdown. The water level fluctuates considerably during the season, however, and the plant can not be run at full capacity at all times. The water is pumped through 900 feet of 12-inch pipe to the highest land to be irrigated and then flows in open cement flumes to the various orchards.

32. D. C. SETTLEMIRE, PORTERSVILLE, CAL. (1910

Location.—SW. ¼ sec. 12, T. 22 S., R. 27 E., Mount Diablo base and meridian.

Plant.—12-horsepower Fairbanks-Morse distillate engine; belt-connected to a Downie geared double pump head. Well, bored, 12 inches by 180 feet; water 33 feet below the surface.

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[1] Bowman, Isaiah, Well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, p. 98, 1911.

Building cost.—Complete plant, $2,500.

Use in 1910.—Irrigation of 9 acres of young orange trees and small garden five times. Will be utilized for irrigation of about 40 acres.

Test.—The following results were obtained during a test of the plant on November 3, 1910:

Consumption of distillate, gallons per hour, 1.00 (owner's record, no satisfactory measurement being obtainable).

Water pumped, gallons per minute, 165.

Speed: Engine, 264 revolutions per minute (66 explosions); pump, strokes per minute, 32.

Head: Cylinder, 100 feet below pump head. Total static head, about 50 feet.

Remarks.—The test of this plant was not wholly satisfactory. The pump was evidently discharging far below its rated capacity and the engine working on a very light load. The efficiency was consequently low. The small discharge could be explained satisfactorily by a worn-out or clogged valve or other similar condition at the cylinder.

Under the conditions of operation in 1910 the costs of irrigation were excessive. With the pump in good condition and the entire 40-acre tract irrigated, however, the costs would be reasonable.

33. G. A. MARTIN, PORTERSVILLE, CAL. (1908).

Location.—SE. ¼ sec. 12, T. 22 S., R. 27 E., Mount Diablo base and meridian.

Plant.—3-horsepower Fairbanks-Morse induction motor; belt-connected to a single-action Krogh pump head with 19-inch stroke. Well, bored, 10 inches by 100 feet; water 60 feet below the surface.

Building cost.—Complete plant, $900.

Use in 1910.—Irrigation of 7 acres of oranges and 3 acres of garden truck five times at the rate of 0.042 to 0.037 acre per hour.

Test.—The following results were obtained during a test of the plant on November 4, 1910:

Current used, 3.3-horsepower (from power company's bill), equivalent to 2.46 kilowatt-hours per hour.

Water pumped, gallons per minute, 38.3.

Speed: Motor, revolutions per minute, 1,800; pump, strokes per minute, 21.

Head: Cylinder, 94 feet below the pump. Total static head, about 70 feet.

Remarks.—The efficiency of this plant is very low, but, aside from the small size of the machinery, no poor working conditions were apparent. The costs, though high, are no doubt warranted by the relatively high returns from citrus culture.

34. R. W. JOB, PORTERSVILLE, CAL. (1910).

Location.—NE. ¼ sec. 13, T. 22 S., R. 27 E., Mount Diablo base and meridian.

Plant.—15-horsepower General Electric induction motor; belt-connected to a No. 3 double-action straight-line deep-well pump with 30-inch stroke. Well, bored, 12 inches by 285 feet; water 80 feet below the surface.

Building cost.—Pump and motor, $2,400; well, $900; complete plant, $3,500.

Use in 1910.—Irrigation of 80 acres of young orange trees five to six times.

Test.—The following results were obtained during a test of the plant on November 4, 1910:

Current used, 15.32-horsepower (from power company's bill), equivalent to 11.43 kilowatt-hours per hour.

Water pumped, gallons per minute, 210.

Speed: Motor, 1,185 revolutions per minute; pump, 16.5 strokes per minute.

Head: Cylinder, 120 feet below the pump. Total static head, about 140 feet.

Remarks.—This plant operates with satisfactory efficiency, and the costs of irrigation are reasonable for citrus culture.

35. BLACHERNE WATER CO., PORTERSVILLE, CAL. (1907).

Location.—SE. $\frac{1}{4}$ sec. 23, T. 21 S., R. 27 E., Mount Diablo base and meridian.

Plant.—15-horsepower Westinghouse induction motor; belt-connected to a No. 30 power head Ames deep-well pump with 24-inch stroke. Well, bored, 10 inches by 112 feet; water about 60 feet below the surface.

Building cost.—Pump, motor, etc., $2,325; well and 12 acres of land, $1,200; complete pumping plant, about $3,500; complete system, including pumping plant, 1,200 feet of 8-inch wood-stave pipe, about 6,600 feet of cement flume, and 12 acres of land, $4,800.

Use in 1910.—Operated practically continuously from April to October, inclusive, for the irrigation of 45 acres of oranges.

Test.—The following results were obtained during a test of the plant on November 5, 1910:

Current used, 16.00 horsepower (from power company's bills), equivalent to 11.9 kilowatt-hours per hour.

Water pumped, gallons per minute, 172.

Speed: Motor, 1,133 revolutions per minute; pump, 22 strokes per minute.

Head: 80 feet below and 125 feet above the power head. Total static head about 205 feet.

Remarks.—This plant pumps water through 1,200 feet of 8-inch wood-stave pipe to a hill crest from which it flows through about 6,600 feet of cement flume to five citrus orchards aggregating 45 acres. The plant is owned and operated by a cooperative stock company, the stockholders being owners of the lands irrigated. Each irrigator is assessed $2 per acre per month for water service. The stave pipe leaks appreciably, but the plant, nevertheless, shows high efficiency. The costs of operation, though high per acre of land irrigated on account of the great lift, are warranted by the value of the citrus-fruit production.

36. HILO PUMP, PORTERSVILLE, CAL. (1904).

Location.—NW. $\frac{1}{4}$ sec. 23, T. 21 S., R. 27 E., Mount Diablo base and meridian.

Plant.—30-horsepower Westinghouse induction motor; direct-connected to a 4-inch Price horizontal centrifugal pump. Well, bored, 12 inches by 165 feet, water 30 feet below the surface.

Building costs.—Complete plant, $3,500.

Use in 1910.—Irrigation of 100 acres of citrus orchards.

Tests.—The following results were obtained during tests on the high and low lifts on November 5, 1910:

Current used, 30.10 horsepower (from power company's bills), equivalent to 22.5 kilowatt-hours per hour.

Water pumped, gallons per minute: High lift, 410; low lift, 383.

Speed: Motor and pump, 868 revolutions per minute.

Head: 92-foot (high) lift; 25.5-foot (low) lift; 25-foot suction. Total static head, 117 feet (high) and 50 feet (low).

Remarks.—This plant pumps water for a small area under the low lift at the pumping plant and for 90 or more acres under the high lift through 700 feet of 12-inch wood-stave pipe to a cement ditch from which distribution is made to the several orchards. An assessment of $1.75 per acre per month is made for water service. Among the expenses of operation are the wages at $22.50 per month of a superintendent, who operates the plant and distributes the water. The efficiency of the plant is good and the costs are reasonable for the lift.

37. COPO DE ORO WATER CO., PORTERSVILLE, CAL.

Location.—SW. ¼ sec. 14, T. 21 S., R. 27 E., Mount Diablo base and meridian.

Plant.—30-horsepower Westinghouse motor; belt-connected to a double plunger Ames pump head, 11-inch cylinder, 28-inch stroke. Well, dug 60 feet, then tunneled and drilled in rock to about 150 feet; water enters about 50 and 150 feet and stands 20 to 30 feet below surface.

Building cost.—Complete plant, $6,000.

Use in 1910.—Irrigation of citrus orchards. Water users charged $1 per hour for use of plant.

Test.—The following results were obtained during a test of the plant on November 5, 1910:

Current used: 23.00 horsepower (from power company's bill), equivalent to 17.15 kilowatt-hours per hour.

Water pumped, gallons per minute, 237.

Speed: Motor, revolutions per minute, 893; pump, 25 strokes per minute.

Head: Cylinder 60 feet below the pump. Total static head about 147 feet.

Remarks.—This plant is located in the center of an area of citrus orchards in a narrow depression between two hills. The location is not favorable for an abundant water supply. Water is pumped through about 1,000 feet of pressure pipe to a concrete flume on the hillside at the upper edge of the citrus orchards. The flume is well constructed and carries the water perhaps a mile to the most distant orchard irrigated. A new plant more favorably located for water supply has been built by the company but was not in operation when visited. Detailed operation statistics were not available.

38. SUNNYSIDE WATER CO., PORTERSVILLE, CAL.

Location.—SW. ¼ sec. 14, T. 21 S., R. 27 E., Mount Diablo base and meridian.

Plant.—50-horsepower Westinghouse motor; belt-connected to two No. 30 power-head Ames double plunger pumps with 24-inch stroke. Three wells, bored, 12 inches by 100 to 150 feet; water 30 to 50 feet below the surface.

Building cost.—Complete plant, $6,000 (?).

Use in 1910.—Irrigation of orange orchard five times.

Test.—The following results were obtained during a test of the plant on November 5, 1910.

Water pumped, gallons per minute, 547.

Speed: Motor, revolutions per minute, 898; pump, 22 strokes per minute.

Head: Cylinder 100 feet below the pump. Total static head, about 180 feet.

Remarks.—Only meager information as to this plant could be secured at the time the brief test was made.

39. J. H. LEACH, PORTERSVILLE, CAL.

Location.—SW. ¼ sec. 23, T. 21 S., R. 27 E., Mount Diablo base and meridian.

Plant.—2-horsepower vertical Fairbanks-Morse distillate engine; belt-connected to a 2-inch Price horizontal centrifugal pump. Well, bored, 6 inches by 80 feet; water 10 feet below surface.

Building cost.—Engine, $120; pump, $35; well, $75; complete plant, $250.

Use in 1910.—As auxiliary to gravity supply for 3 acres of garden, about 300 hours aggregate run.

Test.—The following results were obtained during a test of the plant November 7, 1910:

Consumption of distillate, gallons per hour, 0.15.

Water pumped, gallons per minute, 23.

Speed, revolutions per minute: Engine, 400 (87 explosions); pump, 1,060.

Head: 4-foot lift; 19-foot suction. Total static head, 23 feet.

Remarks.—This is a fair type of the small plant suitable for use in truck gardens. The suction pipe was evidently leaking air somewhat and the efficiency was low. Nevertheless the plant was doing good service as an auxiliary to a gravity water supply. A renewal of the suction pipe would probably be required to place it on an efficient working basis.

40. J. J. ANDERSON, PORTERSVILLE, CAL. (1910).

Location.—Sec. 23, T. 21 S., R. 27 E., Mount Diablo base and meridian.

Plant.—6-horsepower Victor vertical distillate engine; belt-connected to a 6-inch Jackson horizontal centrifugal pump, catalogue capacity 400 gallons per minute. Well bored to 90 feet but filled to 43 feet depth.

Building cost.—Engine and pump, $400; complete plant, $500.

Use in 1910.—Supplement to gravity supply on 17.5 acres of orchard and garden.

Test.—The following results were obtained during a test of the plant on November 7, 1910:

Consumption of distillate, gallons per hour, 0.92 (owner's record).

Water pumped, gallons per minute, 406.

Speed, revolutions per minute: Engine, 370.

Head: 9-foot lift; 22-foot suction. Total static head, 31.

Remarks.—This plant was installed in July, 1910, and used successfully during the season as a supplement to a gravity supply. The plant was unhoused and not in the best of condition. A loose belt caused excess of slip and consequent loss of efficiency. Pump speed could not be measured. The cost per acre, though high, is not unreasonable.

41. BADGER IRRIGATION CO., NEAR EXETER, CAL.

This plant is especially noteworthy for the high lifts. Three primary pumping plants lift the water from wells for the irrigation of low lands and to a reservoir from which a fourth plant lifts it to supply laterals at elevations of 66, 200, 247, 300, and 412 feet above the pumps. The maximum irrigation lift is about 490 feet. As originally planned there were laterals at elevations of 530 and 586 feet above the level of the pumps, but these were abandoned. An orange orchard of 190 acres is irrigated by the system, which is reported by the company to have cost $18,000. The irrigation season is about five and a half months, including parts of April and October.

The following data as to the primary plants were furnished by the company:

1. 7.5-horsepower, type C, Westinghouse induction motor, operating at 110 volts; 6-inch Jackson horizontal centrifugal pump (catalogue capacity 400 gallons per minute).

2. 15-horsepower, type C, Westinghouse induction motor, operating at 110 volts; Hooker double-acting deep-well pump.

3. 7.5-horsepower, type C, Westinghouse induction motor, operating at 110 volts; W. T. Garrett single-acting deep-well pump.

The three plants use about 28.4 horsepower and supply about 2 second-feet of water-

The fourth or high-lift plant is equipped with a 75-horsepower, type C, Westing. house induction motor operating at 2,000 volts and two W. T. Garrett double-acting triplex pumps. These pumps are reported to give a discharge of 1.5 second-feet at all lifts up to the 300-foot level and 1 second-foot at the 412-foot level. The pulley arrangement is such that speeds suitable to the various lifts may be given to the pumps.

The cost of irrigation is necessarily very high with a plant operating under such an unusual head, but it appears to be warranted by the returns from the citrus crops grown. The company officials state that they are satisfied with the results obtained.

42. TOM POGUE, EXETER, CAL (1909).

Location.—SE. $\frac{1}{4}$ sec. 2, T. 19 S., R. 26 E., Mount Diablo base and meridian.

Plant.—5-horsepower General Electric induction motor, operating at 220 volts; belt-connected to a Garrett single-acting deep well pump, 8-inch cylinder. Well bored 12 inches by 112 feet, water 36 feet below the surface.

Building cost.—Pump, $540; well, $100; complete plant, $1,400.

Use in 1910.—Irrigation of garden, orchard, and alfalfa.

Test.—The following results were obtained during a test of the plant on November 9, 1910:

Current used: 5.05 horsepower (from power company's bill), equivalent to 3.8 kilowatt-hours per hour.

Water pumped, gallons per minute, 179.

Speed: Motor, revolutions per minute, 1,167; pump strokes per minute, 29.

Head: Cylinder 60 feet below the pump; lift 13 feet. Total static head, about 60 feet.

Remarks.—This plant was giving satisfactory results.

43. P. W. PRESTON, EXETER, CAL. (1907).

Location.—E. $\frac{1}{2}$ NW. $\frac{1}{4}$ sec. 2, T. 19 S., R. 26 E., Mount Diablo base and meridian.

Plant.—10-horsepower Fairbanks-Morse distillate engine, 39-inch pulley; belt-connected to a 4-inch Price horizontal centrifugal pump with 8-inch pulley. Well, bored, 8 inches by 90 feet in pit 35 feet deep; water 36 feet below the surface.

Building cost.—Engine, $550; pump and pipe, $151; well and pit, $200; complete plant, $1,000.

Use in 1910.—Irrigation of 26 acres of citrus fruits.

Test.—The following results were obtained during a 2-hour test of the plant on November 9, 1910:

Consumption of distillate, gallons per hour, 1.00 (approximate).

Water pumped, gallons per minute, 320.

Speed, revolutions per minute: Engine, 274 (105 explosions); pump, 1,320.

Head: 37-foot lift; 14-foot suction. Total static head, 51 feet.

Remarks.—This plant was giving good service. It is of sufficient capacity to irrigate a considerably larger area than it serves, but the cost per acre is warranted for citrus culture.

44. L. W. SHAW, EXETER, CAL. (1910).

Location.—W. $\frac{1}{2}$ SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 35, T. 18 S., R. 26 E., Mount Diablo base and meridian.

Plant.—8-horsepower Samson distillate engine, 28-inch pulley; belt-connected to a $3\frac{1}{2}$-inch Samson horizontal centrifugal pump with 7-inch pulley, catalogue capacity of 250–300 gallons per minute. Well, bored, 10 inches by 90 feet; water 36 feet below the surface.

Building cost.—Well, $300; complete plant, $1,000.

Use in 1910.—Irrigation of 15 acres of oranges and about 4 acres of alfalfa. About 800 gallons of distillate used.

Test.—The following results were obtained during a test of the plant on November 9, 1910:

Consumption of distillate, gallons per hour, 0.875.

Water pumped, gallons per minute, 220.

Speed, revolutions per minute: Engine, 263; pump, 1,004.

Head: 31-foot lift; 24-foot suction. Total static head, 55 feet.

Remarks.—The efficiency of this plant was only fair. The pump was underspeeded, but even under this condition the water was drawn down so far as to create a rather

large suction head. The machinery was apparently in good condition, the faults of the plant being in design. The pump is too high above the water level and the pulley size not in proper ratio.

45. MR. BRISCOE, LINDSAY, CAL. (1910).

Location.—NE. ¼ sec. 30, T. 19 S., R. 27 E., Mount Diablo base and meridian.

Plant.—3-horsepower General Electric induction motor direct-connected to a 2-inch type B Krogh horizontal centrifugal pump, catalogue capacity of 100 gallons per minute. Well, bored, 10 inches by 80 feet, filled up to 54-foot depth.

Building cost.—Pump and motor, $425; well, $300; complete plant, $900.

Test.—The following results were obtained during a test of the plant on November 10, 1910:

Current used: 3.59 horsepower (from power company's bill), equivalent to 2.68 kilowatt hours per hour.

Water pumped, gallons per minute, 116.

Speed, revolutions per minute, 1,800.

Head: 28-foot lift; 18-foot suction. Total static head, 46 feet.

Remarks.—The power consumption at this plant is unreasonably high, with consequent low efficiency. The cause of excessive power use was not apparent.

46. O. S. GARD, LINDSAY, CAL.

Location.—NW. ¼ sec. 31, T. 19 S., R. 27 E., Mount Diablo base and meridian.

Plant.—3-horsepower Bullock motor direct-connected to a 2-inch Eclipse horizontal centrifugal pump. Well, bored, 10 inches by 77 feet; pit 32 feet deep.

Building cost.—Complete plant, $350.

Use in 1910.—Irrigation of 20 acres of oranges with four months' steady operation.

Test.—The following results were obtained during a test of the plant on November 10, 1910:

Current used: 3.47 horsepower (from power company's bill), equivalent to 2.59 kilowatt hours per hour.

Water pumped, gallons per minute, 72.

Speed, revolutions per minute, 1,700.

Head: 10-foot lift; 30-foot suction. Total static head, 40 feet.

Remarks.—The pump and motor were installed so that they could be raised or lowered by sliding in a frame. When tested the pump and motor had been raised nearly to the surface for the winter and was practically out of commission. The suction head was therefore very great and the indicated efficiency of the plant low. The test does not show what the plant could do under normal conditions.

47. HILL PLANT OF DR. C. B. ROOT, LINDSAY, CAL.

Locations.—NE. ¼ sec. 6, T. 20 S., R. 27 E., Mount Diablo base and meridian.

Plant.—7½-horsepower Westinghouse type C induction motor; belt-connected to a double-acting Whitmer deep-well pump. Well, bored, 203 feet deep; water, 60 feet below the surface. Discharge through 750 feet of 4-inch pipe.

Building cost.—Well, $200; complete plant, $1,500.

Use in 1910.—In conjunction with plant No. 48, used for the irrigation of 70 acres of oranges.

Test.—The following results were obtained during a test of the plant on November 10, 1910:

Current used: 7.44 horsepower (from power company's bill), equivalent to 5.55 kilowatt-hours per hour.

Water pumped, gallons per minute, 96.

Speed: Motor, revolutions per minute, 1,143; pump, strokes per minute, 32.

Head: 75 feet above and about 75 feet below the power head. Total static head 150 feet.

Remarks.—This plant has been in use several years and has given reasonably satisfactory service throughout.

48. LOW-LEVEL PLANT OF DR. C. B. ROOT, LINDSAY, CAL.

Location.—NE. ¼ sec. 6, T. 20 S., R. 27 E., Mount Diablo base and meridian.

Plant.—7½-horsepower Westinghouse type C induction motor; belt-connected to a double-cylinder, single-plunger Garrett deep-well pump. Well, bored, 201 feet deep.

Building cost.—Well, $500; complete plant, $1,500.

Use in 1910.—In conjunction with plant No. 47, used for the irrigation of 70 acres of oranges.

Test.—The following results were obtained during a test of the plant on November 10, 1910:

Current used: 7.92 horsepower (from power company's bill), equivalent to 5.91 kilowatt-hours per hour.

Water pumped, gallons per minute, 161.

Speed: Motor, revolutions per minute: 1,165; pump strokes per minute, 28.

Head: 25 feet above and about 75 feet below the power head. Total static head 100 feet.

Remarks.—This is a well-kept plant that gives satisfactory results. The pumped water is distributed through cement pipe.

49. ROEDING & WOOD NURSERY CO., EXETER, CAL. (1909).

Location.—NE. ¼ sec. 14, T. 19 S., R. 26 E., Mount Diablo base and meridian.

Plant.—40-horsepower Western distillate engine; belt-connected to a No. 28 power head, single-acting Pomona deep-well pump. Well, bored, 15 inches by 100 feet; cylinder 68 feet down; 86 feet to main aquifer.

Building cost.—Engine and pump, $3,370; building, $250; well, $500. Complete plant about $4,120, exclusive of iron-pipe line nearly a mile long.

Use in 1910.—For irrigation of 13 acres of alfalfa and 5 acres of citrus nursery at plant and about 160 acres of olives and nursery at high levels; being used as supplement to gravity supply on 100 acres of this area.

Test.—The following results were obtained during a test of the plant on November 11, 1910.

Consumption of distillate, gallons per hour, 1.50.

Water pumped, gallons per minute, 393.

Speed: Engine, revolutions per minute, 224 (28 explosions); pump, strokes per minute, 18.

Head: 5 feet above and 38 feet below the pump head. Total static head, 43 feet.

Remarks.—The plant is designed for operation under widely differing conditions. At the plant about 25 acres, chiefly in alfalfa and nursery trees, is to be irrigated. The greater part of the irrigable area, however, is located at the edge of the foothills, nearly a mile distant. The owners report that at the end of 3,760 feet of 7⅝-inch pipe the total head, including friction, is 173.5 feet, and the pump delivers 1.03 second-feet against this head when the engine uses 2.75 gallons per hour of distillate. An additional 1,000 feet of pipe carries the water to a level 150 feet higher, where about 0.5 second-foot can be delivered. The test made was on the lowest lift, where the operation would be least economical.

50. LAUREL COLONY, TULARE, CAL. (1903).

Location.—Sec. 36, T. 19 S., R. 23 E., Mount Diablo base and meridian.

Plant.—10-horsepower Westinghouse type C induction motor, direct-connected to a 6-inch Krogh California centrifugal pump. Well, bored, 10 inches by 465 feet.

Building cost.—Well, $1,800; machinery, $1,000; complete plant, $3,000.

Use in 1910.—Irrigation of 320 acres, chiefly alfalfa land.

Test.—The following results were obtained during a test of the plant on November 14, 1910:

Current used: 14.00 horsepower, equivalent to 10.4 kilowatt-hours per hour.

Water pumped, gallons per minute, 910.

Speed, revolutions per minute, 1,100.

Head: Lift, 10 feet; suction, 20 feet. Total static head 30 feet.

Remarks.—This plant is noteworthy for the relatively high cost of the well. It is located in an artesian belt and the water rises within 1.5 feet of the surface. Flowing wells are not unusual in the locality. The plant is operated for the benefit of several settlers. The costs per acre are low, the capacity duty being about 1 second-foot to 160 acres. The motor is run at considerable overload. A second plant of about the same size would be required to produce maximum yields from the entire area covered.

51. DR. M. S. CHARLES, TULARE, CAL. (1910).

Location.—Sec. 4, T. 20 S., R. 24 E., Mount Diablo base and meridian.

Plant.—3-horsepower Westinghouse type CCL induction motor; belt-connected to a 2-inch Golden West horizontal centrifugal pump. Well, bored, 5 inches by 70 feet.

Building cost.—Motor and transformer $210; complete plant, including 460 feet of 4-inch pipe, $518.

Use in 1910.—Irrigation of 32 acres of garden and alfalfa land.

Test.—The following results were obtained during a test of the plant on November 15, 1910:

Current used: 4.5 horsepower (from company's test) equivalent to 3.36 kilowatt-hours per hour.

Water pumped, gallons per minute, 135.

Speed, revolutions per minute: Motor, 1,702; pump, about 1,490.

Head: 9-foot lift; 16-foot suction. Total static head, 25 feet.

Remarks.—The apparent efficiency of this plant is very low. The machinery was new and the installation seemed to be first class. The consumption of power had been tested by the company shortly before test on November 15. A ground on the electric circuit or an obstruction in the discharge pipe would seem to be the most likely difficulties.

52. G. H. HAUSCHILDT, TULARE, CAL.

Location.—Sec. 5, T. 20 S., R. 24 E., Mount Diablo base and meridian.

Plant.—3-horsepower Westinghouse type CCL induction motor, direct-connected to a 3-inch Krogh California horizontal centrifugal pump. Well, bored, 10 inches by 850 feet.

Building cost.—Well, $1,480; complete plant, $2,020.

Use in 1910.—Irrigated 40 acres of alfalfa four times with about 6 inches of water.

Test.—The following results were obtained during a test of the plant on November 16, 1910:

Current-used: 3.42 horsepower (from power company's bill), equivalent to 2.55 kilowatt-hours per hour.

Water pumped, gallons per minute, 180.

Speed, revolutions per minute, 1,700.

Head: 10-foot lift; 19-foot suction. Total static head, 29 feet.

Remarks.—Discharge is through 150 feet of 6-inch wood-stave pipe to a 0.5-acre reservoir, which is used to store water at night and afford a larger irrigation head.

53. F. S. McADAMS, TULARE, CAL. (1910).

Location.—SW. ¼ sec. 13, T. 20 S., R. 23 E., Mount Diablo base and meridian.

Plant.—10-horsepower General Electric induction motor; direct-connected to a 5-inch Price horizontal centrifugal pump. Well, bored, 12 inches by 163 feet; cased.

Building cost.—Well, $325; complete plant, $845.

Use in 1910.—Irrigation of 90 acres of alfalfa. Planned to irrigate 120 acres. Operated continuously from April to August 1.

Test.—The following results were obtained during a test of the plant on November 18, 1910:

Current used: 9.7 horsepower (10.25 horsepower from power company's bill).

Water pumped, gallons per minute, 720.

Speed, revolutions per minute, 1,172.

Head: 6-foot lift; 22-foot suction. Total static head 28 feet.

Remarks.—This is one of the better class plants and is operated so as to give relatively low costs per acre irrigated.

54. W. J. McADAMS, TULARE, CAL. (1909).

Location.—SW. ¼ sec. 18, T. 20 S., R. 24 E., Mount Diablo base and meridian.

Plant.—15-horsepower Westinghouse type CCL induction motor, direct-connected to a 7-inch Price horizontal centrifugal pump. Wells, bored, 12 inches in diameter, one 90 feet and the other 127 feet in depth.

Building cost.—Pump and motor, $750; complete plant, $1,400.

Use in 1910.—Irrigation of 200 acres of alfalfa. Operated continuously for 6 months. Additional area of 40 acres being prepared for irrigation.

Test.—The following results were obtained during a test of the plant on November 18, 1910:

Current used: 19.21 horsepower (from power company's bill), equivalent to 14.34 kilowatt-hours per hour.

Water pumped, gallons per minute, 1,450 (approximately).

Speed, revolutions per minute, 846.

Head: 10-foot lift; 19-foot suction. Total static head, 29 feet.

Remarks.—This plant is typical of the best practice for irrigation of alfalfa.

55. L. G. MARTIN, TULARE, CAL. (1910).

Location.—NW. ¼ sec. 18, T. 20 S., R. 24 E., Mount Diablo base and meridian.

Plant.—10-horsepower Alamo distillate engine, 24-inch pulley, belt-connected to a 5-inch Price horizontal centrifugal pump, 8.5-inch pulley. Well, bored, 12 inches by 110 feet.

Building cost.—Well, $220; engine and pump, $650; complete plant, $900.

Use in 1910.—Installed in late summer and used for watering stock and irrigating 40 acres of alfalfa. Will be used for irrigation of 80 acres of alfalfa.

Test.—The following results were obtained during a test of the plant on November 18, 1910:

Consumption of distillate, gallons per hour, 1.45.

Water pumped, gallons per minute, 695.

Speed, revolutions per minute: Engine, 264; pump, 695.

Head: 9-foot lift; 17-foot suction. Total static head, 26 feet.

Remarks.—This is a new plant and the operation shows rather low efficiency. The vacuum gage showed loss of head in the suction pipe, probably due to some obstruction.

TABULATED RESULTS OF PUMPING TESTS.

In Table 34 the data derived from the preceding pumping plant tests and information collected at the time the tests were made are assembled so as to present in concise form the chief factors of engineering interest in each case.

The number in the first column corresponds to the number used in the description of each plant and its test.

The second and third columns give the discharge in gallons per minute and in second-feet, generally as determined by test, though in a few specified cases as reported by the owner or operator of the plant.

The fourth column, of drawdown, shows the extent to which the water level in the wells was lowered during the tests. Generally about 20 minutes was required to reduce the water level to an elevation that remained constant thereafter with uniform discharge from the plant.

The capacity of the well (column 5) is derived from the third and fourth columns, being the discharge in second-feet divided by the drawdown in feet. This capacity is only an average figure, however, as each succeeding foot of drawdown probably causes an increasingly greater yield of the well.

The total static head represents the difference in elevation between the water level in the well during operation and the level at which the water is discharged from the pumping plant.

The useful water horsepower is derived from the discharge and the total static head, being the discharge in pounds per second (the discharge in second-feet × 62.3) multiplied by the total static head in feet, divided by 550 (the number of foot-pounds per second in one horsepower).

The column giving the length of irrigation season in days is based on what information could be secured as to the customary period during which crops were irrigated in the several localities examined.

In the ninth column is shown in terms of days of continuous operation the length of time the plants were operated in 1910. Comparison of this column with that preceding indicates that in general the plants were operated for only a small part of the irrigating season. This shows one of the principal sources of the high cost of irrigation by pumping, for the fixed costs on a pumping plant that is lying idle mount up rapidly and result in a high cost per acre actually irrigated.

The columns giving capacity of plant show respectively the amounts of water that could be delivered if the plants were operated 80 per cent of the irrigation season, and the amounts that were actually delivered in 1910. These columns show, like columns 8 and 9, that the large proportion of the time that the plants are idle is a principal factor in making the cost of pumping higher than is necessary.

The figures of column 12, giving the acreage irrigable with maximum draft of 1 second-foot to 80 acres, is obtained from the figures in column 3, the actual discharge in second-feet. The acreages actually irrigated in 1910 are given in column 13.

Column 14, giving the duty of water in 1910 (obtained from the figures of columns 11 and 13), is of principal interest in showing the variation in irrigation practice among individual ranchers. The figures also indicate roughly the amount of water actually delivered to the land for irrigation.

The item of fuel oil has been expressed in three ways—the amount of fuel oil (distillate) used per hour by the engines tested and the corresponding costs per day and per useful water horsepower per day. The cost of fuel oil was taken as the cost delivered at the plants and ranged from 8 cents to 13 cents per gallon of distillate in various parts of the valley. In the lower part of the table under the same columns the electric power consumed at motor-driven plants is shown. In general these plants were not provided with meters and no means for testing power consumption were available. The results shown, therefore, are taken in most instances from power companies' bills. It is the custom of the power companies to test the plants from one to three times during the irrigation season and to charge for power used on the basis of the maximum amount consumed during their tests.

The figures of the building cost represent the cost of the completed pumping plants. The total costs are based on the most reliable information obtainable, including statements of owners and of the companies installing the machinery. From these total costs the cost per acre with maximum draft of 1 second-foot to 80 acres and the cost per acre irrigated in 1910 are obtained from the corresponding columns of the area irrigable.

The annual cost of depreciation, renewals, and repairs is based on the assumption that for a distillate plant these costs will amount to 15 per cent per year on the cost of the machinery and for a motor-driven plant to 8 per cent per year on the cost of the machinery. These values, if anything, are lower than the actual and do not depend very largely on the amount of use given the plant during the year, for the depreciation of machinery may be as great during periods of nonuse as during periods of use; in other words a plant may "rust out" as quickly as it would "wear out." There is of course a considerable variation in the sum total represented by the three items, depending on the care given to the machinery. In order to make a comparison of the various plants, however, a uniform percentage was used throughout, though the actual cost of all the machinery was not exactly that recorded in the notes on the tests. The item of taxes was not included with the other fixed charges, since a reliable

value to be applied was not determined upon, but in other similar studies taxes have been figured as a per cent per year on the first cost.[1] Interest on the investment, another element of fixed charges, in the amount of 6 to 8 per cent on the first cost is also omitted from the items in the table.

In computing the annual cost of fuel (or current), labor, and lubrication, the fuel or current cost for the first column—involving 80 per cent continuous operation—is obtained from the figures of length of irrigation season in days and the fuel or current cost per 24 hours. For the fuel or current cost with operation as in 1910, the figures of continuous equivalent operation in days in 1910 and the fuel or current cost per 24 hours are used. To the costs of fuel alone thus obtained, 2 cents per hour of operation for distillate plants, 5 cents per hour for the steam plant, and 1 cent for motor-driven plants was added in order to cover the charges of labor and lubrication.

The figures of total annual cost of maintenance and operation are obtained from preceding data. The total costs are in each case the sum of the annual cost of fuel (or current), labor, lubrication, depreciation, renewals, and repairs. As has been previously stated, the items of taxes and interest on investment have not been included, but they probably would add an annual sum equal to about 7 to 9 per cent of the total building cost. The costs per acre are these total costs divided by the appropriate values for the area irrigable or irrigated. The costs per acre-foot of water pumped represent the total costs divided by the capacity of the plant in acre-feet per season. The total cost per acre-foot of water per foot of static head is the total cost per acre-foot of water pumped, divided by the static head.

The last column indicates the relative efficiency of the plants in percentages. To determine the figures in this column it was assumed that a gallon of distillate should produce 8 horsepower hours of energy in a plant of fairly good design. A comparison on this basis of the amount of fuel oil used with the useful water horsepower developed gives the efficiency. For example, in plant No. 1, 0.96 gallon of distillate per hour yielded 1.68 useful water horsepower, but on the basis of 1 gallon of distillate per hour to 8 useful water horsepower 0.96 gallon should yield 7.68 horsepower. The efficiency is therefore 1.68 divided by 7.68, or 22 per cent. For the steam plant it was assumed that 1 gallon of crude oil should produce 2.5 horsepower. Similarly, for motor-driven plants, comparison of the horsepower of electric energy used or paid for with the useful water horsepower developed gives the efficiency.

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[1] Smith, G. E. P., Ground-water supply and irrigation in the Rillito Valley: Arizona Univ. Agr. Exper. Sta. Bull. 64, p. 209, 1910.

SUMMARY OF PUMPING TESTS.

The irrigator is sometimes apt to consider only the actual expenses of operation of a plant when figuring on the cost of pumping water. The cost of irrigation by pumping, however, includes properly both the cost of operation and all fixed charges, such as interest on the investment, depreciation, taxes, and repairs.

In the descriptions of the individual pumping plants tested, attention has in several instances been called to one or more of the specific factors that render the plant a relatively expensive source of water supply. In summarizing the results of the tests these factors may properly be mentioned again and their effects on the cost of irrigation emphasized.

Most of the pumping plants in San Joaquin Valley are well housed, but this important matter is not always properly attended to. The rapid depreciation of pumping as well as other kinds of farm machinery if not taken care of is very real, and depreciation is an important factor in the cost of irrigation water obtained from wells.

In the tabulated results of pumping tests the depreciation charge has been combined with those for renewals and repairs, the total of the three being taken as 15 per cent per year for distillate plants and 8 per cent per year for motor-driven plants. These figures are believed to be conservative, since in similar tests by others the depreciation charge alone for gasoline plants has been taken as from 10 to 12 or 15 per cent and for motor-driven plants as from 6 to 7 or 9 per cent.[1] It will be noted that in the tabulated data summarizing the tests in San Joaquin Valley, interest and taxes have not been included with the other fixed charges. They probably should be taken as adding to these charges about 7 to 9 per cent per year on the value of the plant.

The tendency throughout the valley is to install pumping machinery capable of more work than is required of it. This custom may be in part attributable to the sellers of the machinery, who are of course desirous of making large sales; but the installation of large plants appears also to be followed as a matter of convenience in operation. The irrigator finds it easier to run a large pumping unit for a few hours than to accomplish the same amount of irrigation with a smaller plant requiring perhaps several days to supply the same acreage with water. The interest on the greater amount of capital tied up in the larger plant and the increased amount that must be charged to depreciation form very considerable items in the total annual cost of irrigation, however. In places where a larger plant has been installed

[1] Le Conte, J. N., and Tait, C. E., Mechanical tests of pumping plants in California: U. S. Dept. Agr. Office Exper. Sta. Bull. 181, pp. 51-52, 1907.
Smith, G. E. P., Ground-water supply and irrigation in the Rillito Valley: Arizona Univ. Agr. Exper. Sta. Bull. 64, p. 209, 1910.

	Annual cost of depreciation, renewals, and repairs.	Annua[l] fuel (labor catio[n] — With 8[0] per cen[t] continu ous operation.
	$48	$24.
	54	25.
	49	20
	96	29.
	115	29.
	128	42.
	64	35
	153	37
1	81	25
1	100	29.
1 2	200	72
1	37	21
1	100	30.
1	39	24
1	180	....
2	96	....
2	....	....
2	81	59
2	210	1,32
2	250	1,38
3	350	2,46
5	98	57
3	285	80
3	25	20.
4	60	67
4	105	75
4	100	67
4	460	1,54 / 88 / 1,54
2	450	1,28
	40	48
1	16	20
2	128	2,93
2	40	92
2	130	2,48
5	80	38
5	20	14
5	20	12
5	35	29
5	60	51
3	80	1,20
3	50	21
3	190	81
3	186	85
3	100	1,55
	....	....
3	240	1,20
4	800	3,55
4	70	30
4	36	23
4	16	22
4	70	42
4	70	44

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TABLE 34.—*Summary of pumping-plant data.*

Test No.	Discharge: Gallons per minute.	Discharge: Second-feet.	Draw-down.	Capacity per well (second-foot per foot of draw-down).	Total static head.	Useful water horsepower.	Length of irrigation season.	Continuous equivalent of operation in 1910.	Capacity of plant (acre-feet per season): With 80 per cent continuous operation.	Capacity of plant: With operation as in 1910.	Area irrigable (acres): With maximum draft of 1 second-foot to 80 acres.	Area irrigable: With operation as in 1910.	Duty of water in 1910, acre-feet per acre.	Power, Distillate: Gallons per hour.	Power, Distillate: Cost per 24 hours.	Power, Distillate: Cost per 24 hours per useful water horsepower.	Building cost: Total.	Building cost: Cost per acre irrigable with maximum draft of 1 second-foot to 80 acres.	Building cost: Cost per acre irrigated in 1910.	Annual cost of depreciation, renewals, and repairs.	Annual cost of fuel (or current), labor, and lubrication: With 80 per cent continuous operation.	Annual cost of fuel (or current), labor, and lubrication: With operation as in 1910.	Total annual cost of maintenance and operation, with 80 per cent continuous operation and maximum draft of 1 second-foot to 80 acres: Total.	Per acre.	Per acre-foot of water pumped.	Per acre-foot of water per foot of static head.	Total annual cost, with operation as in 1910: Total.	Per acre.	Per acre-foot of water pumped.	Per acre-foot of water per foot of static head.	Relative efficiency.
			Feet.		Feet.		Days.	Days.																							Per cent.
1	256	0.57	18	0.032	26	1.68	120	7.3	109	8.3	46	4	2.1	0.96	$2.07	$1.23	$385	$8.40	$96	$48	$245	$19	$293	$6.40	$2.70	$0.104	$67	$17	$8.10	$0.31	22
2	380	.85	10	.085	21	2.02	120	5.7	162	9.6	68	5	1.9	1.00	2.16	1.07	495	7.30	99	54	255	15	309	4.50	1.90	.090	89	14	7.20	.34	25
3	265	.59	15	.039	27	1.81	120	8.7	113	10.2	47	10	1.0	.75	1.62	.90	400	8.50	40	49	202	18	251	5.30	2.20	.082	67	6.70	6.60	.24	30
4	868	1.93	19	.034	27	5.93	120	11.7	368	45	154	20	2.2	1.20	2.59	.44	1,250	8.10	62	96	295	36	391	2.50	1.10	.040	132	6.60	2.90	.11	62
6	605	1.35	15	.090	31	4.75	120	30	257	80	108	57	1.4	1.20	2.59	.55	1,000	9.30	18	115	295	92	410	3.80	1.60	.051	207	3.60	2.60	.08	49
7	914	2.04	10	.204	28	6.46	120	4.8	389	19	163	4	4.8	1.83	3.95	.61	1,200	7.40	300	128	425	21	553	3.40	1.40	.051	149	37	7.80	.28	44
8	406	.90			26	2.65	120	4.2	171	7.5	72	2.5	3.0	1.50	3.24	1.22	550	7.60	220	64	357	16	421	5.80	2.50	.035	80	32	10.70	.41	22
9	425	.95	22	.043	48	5.15	120	11.2	180	21	76	14	1.5	1.57	3.39	.66	1,300	17	93	153	371	43	524	6.90	2.90	.061	196	14	9.30	.19	41
10	444	.99	8	.124	27	3.00	120	9.0	188	18	79	4	4.5	1.00	2.16	.72	650	8.20	162	81	253	24	334	4.20	1.80	.066	105	26	5.80	.22	38
11	444	.99	13	.076	27	3.00	120		188		79	60		1.20	2.59	.86	900	11	15	100	295		395	5.00	2.10	.078					31
19 and 20	672	1.50	16	.094	28	4.76	120	29	497	150	209	40	3.8	1.87	4.04	.85	2,000	9.60	50	200	720	218	920	4.40	1.80	.067	418	10	2.80	.10	32
21	500	1.11	13	.085	27	3.41								1.38	2.98	.87															81
13	249	.55	10	.055	24	1.52	120	6.3	105	6.9	44	2.3	3.0	.80	1.73	1.14	325	7.40	141	37	212	14	249	5.70	2.40	.100	51	22	7.40	.31	24
14	299	.67	18	.037	35	2.65	120	17.7	128	23.5	54	6.0	3.9	1.25	2.70	1.02	1,000	18	167	100	305	56	405	7.50	3.20	.090	156	26	6.60	.19	26
18	406	.90	10	.083	23	2.36	120	9.7	171	16.0	72	3.5	4.6	.97	2.10	.89	355	4.90	102	39	248	25	287	4.00	1.70	.074	64	18	4.00	.17	30
16 [a]	5,750	12.8	0		3.9	5.67		5.6		142		77	1.8	1.42	3.41	.60	1,500		20	180		22					202	2.60	1.40	.36	50
24	765	1.70	15	.113	30	5.80											760			96											
25 [b]	450	1.00	20	.050	32	3.64																									
25 [b]	400	.89	16	.056	28	2.83	180	27	254	48	71	28	1.7	1.61	3.67	1.30	700	9.90	25	81	598	112	679	9.60	2.70	.098	193	6.90	4.00	.14	22
28	780	1.74	22	.040	42	8.28	180	21	497	72	139	60	[c] 1.2	3.80	8.66	1.05	3,200	23	53	210	1,320	192	1,530	11.00	3.10	.073	402	6.70	5.60	.13	27
29	1,900	4.24	25	.085	46	22.1	180	32	1,210	269	339	100	2.7	4.00	9.12	.41	3,500	10	35	250	1,380	307	1,630	4.80	1.30	.030	557	5.60	2.10	.05	69
30	1,080	2.41	31	.026	82	22.4	180	15	688	72	193	58	1.2	7.27	16.60	.74	6,500	34	112	350	2,460	257	2,810	11.60	4.10	.050	607	10	8.40	.10	39
55	695	1.55	13	.119	26	4.57	180	[d] 94	443	288	124	[d] 80	[d] 3.6	1.45	3.48	.76	900	7.30	11	98	570	372	668	5.40	1.50	.058	470	5.90	1.60	.06	39
32	165	.37			50	2.09	270	10.4	159	7.7	60	9	.9	1.00	3.24	1.55	2,500	42	278	285	804	39	1,089	18.20	6.80	.136	324	36	42.10	.84	26
39	23	.051			23	.13	270	13	22	1.3	8	3	.4	.15	.47	3.50	250	31	83	25	205	12	230	28.70	10.50	.450	37	12	28.50	1.24	11
40	406	.90			31	3.17	270	15	386	27	144	17.5	1.5	.92	2.65	.84	500	3.50	29	60	676	47	736	5.10	1.90	.061	107	6.10	4.00	.13	43
43	320	.71	13	.055	51	4.13	270	42	304	58	114	26	2.2	1.00	3.00	.73	1,000	8.80	38	105	752	146	857	7.50	2.80	.055	251	9.70	4.30	.08	52
44	220	.49	16	.030	55	3.06	270	38	210	37	78	20	1.8	.88	2.64	.86	1,000	13	50	100	674	119	774	9.90	3.70	.067	219	11	5.90	.11	43
49	[e] 461	1.03			144	16.8	270		441		165	[f] 185		2.75	6.60	.39	4,120		22	460	1,540		2,000	12.10	4.50	.032					76
	393	.88			43	4.27	270		377		141			1.50	3.60	.84					880		1,340	9.50	3.60	.083					36
	[e] 225	.50			294	16.7	270		214		80			2.75	6.60	.39					1,540		2,000	25	9.30	.032					76
														Steam plant, crude oil fuel.																	
27	1,320	2.94	18	.082	41	13.7	180	12.5	840	73	235	120	.6	14.0	7.60	.55	3,500	15	29	450	1,280	109	1,730	7.40	2.10	.050	559	4.70	7.60	.19	39
														Electric power.																	
5	300	.67			20	1.51	120		128		54	2		4 kw. hours per hour, at 5c			550	10	275	40	484		524	9.70	4.10	.205					28
12	108	.24	8	.030	25	.68	120	5.2	46	2.5	19	1.5	1.7	2 kw. hours per hour, at 4c			250	13	167	16	207	11	223	11.70	4.80	.194	27	18	10.80	.43	25
22	2,160	4.81	20	.080	28	15.3	180		1,370		385	4		28 (?) kw. hours per hour, at 3c			3,000	7.80		128	2,936		3,064	8.00	2.20	.080					41
23	630	1.40	14	.100	20	3.18	180		400		112	18		8.6 kw. hours per hour, at 3c			808	7.20	45	40	928		968	8.60	2.40	.120					28
26	2,300	5.12	20	.085	41	23.8	180	167	1,460	1,700	110	730	2.3	49.0 horsepower, at $50			3,000	7.30	4.10	130	2,485	2,490	2,615	6.40	1.80	.044	2,631	3.60	1.50	.04	49
50	910	2.03	12	.170	30	6.90	180		580		162	320		14.0 horsepower, at $25			3,000	18	9.40	80	385		465	2.90	.80	.027					49
51	135	.30			25	.85	180		86		24	32		4.5 horsepower, at $25			518	22	16	20	147		167	7.00	1.90	.078					19
52	180	.40			29	1.32	180	101	114	80	32	40	2.0	3.42 horsepower, at $25			2,020	63	50	20	120	109	140	4.40	1.20	.042	120	3.20	1.60	.06	39
53	720	1.60			28	5.10	180	120	457	380	128	90	4.2	10.25 horsepower, at $25			845	6.60	9.40	35	241	285	326	2.50	.71	.025	320	3.60	.84	.03	50
54	1,450	3.23			29	10.6	180	180	922	1,150	258	200	5.8	19.21 horsepower, at $25			1,400	5.40	7	60	515	523	575	2.20	.62	.022	583	2.90	.51	.02	55
31	505	1.26	1.7	.247	79	11.3	270	210	540	525	202	177	3.0	23.00 horsepower, at $50			1,300	6.40	7.30	80	1,202	1,200	1,282	6.30	2.40	.030	1,280	7.20	2.40	.03	49
33	38	.085			70	.68	270	54	36	9.1	14	10	.9	3.30 horsepower, at $50			900	64	90	50	217	178	267	19.10	7.40	.106	228	23	25.30	.36	21
34	210	.47			140	7.44	270	130	201	121	75	80	1.5	15.32 horsepower, at $50			3,500	47	41	190	818	797	1,008	13.40	5.00	.036	987	12	8.20	.06	49
35	172	.38			205	8.91	270	210	164	159	61	45	3.5	16.00 horsepower, at $50			3,500	57	78	186	852	850	1,038	17.00	6.30	.031	1,036	23	6.50	.03	56
36	410	.90	20	.045	117	12.1	270	210	385	375	144	100	3.8	30.10 horsepower, at $50			3,560	24	35	100	1,557	1,555	1,657	11.50	4.30	.037	1,655	17	4.40	.04	40
	383	.85			50	4.84																									
37	237	.53			147	8.80	270		227		85			23.00 horsepower, at $50			6,000	71		240	1,202		1,442	17.00	6.30	.043					38
41	450-675	1.00-1.50			146-492	25-56	270	170	643	506	240	190	2.7	70.00 horsepower, at $50			18,000			800	3,550	3,540	4,350	18.10	6.80	.046-.014	4,340	23	8.60	.06-.02	
42	180	.40			60	2.73	270		171		64			5.05 horsepower, at $50			1,400	22		70	304		374	5.80	2.20	.037					54
45	116	.26			46	1.35	270		111		42			3.59 horsepower, at $50			900	21		36	232		268	6.40	2.40	.052					38
46	[g] 72	.16			40	.73	270	120	69	38	26	20	1.9	3.47 horsepower, at $50			350	13	18	16	226	203	242	9.30	3.50	.088	219	11	5.80	.14	21
47	96	.21			150	3.64	270	180	92	76	34	70	2.9	7.44 horsepower, at $50			1,500	44	43	70	424	415	494	14.50	5.40	.036	485	14	6.40	.04	49
48	161	.36			100	4.07	270	180	154	128	57			7.92 horsepower, at $50			1,500	26		70	448	439	518	9.10	3.40	.034	509		4.00	.04	51

NOTES.—The cost per gallon of distillate was 9 cents delivered, except as follows: 9.5 cents for tests numbered 25, 28, 29, and 30; 10.0 cents for tests numbered 16, 49, and 55; 12.0 cents for test numbered 40; 12.5 cents for tests numbered 43 and 44; 13.0 cents for test numbered 39; and 13.5 cents for test numbered 32. With 80 per cent continuous operation and maximum draft of 1 second-foot to 80 acres, the duty of water is 2.4 acre-feet per acre per annum for a season of 120 days and 3.6 acre-feet per acre per annum for a season of 180 days. In all cases where a season of 270 days is indicated, the plants are used for orchard irrigation, chiefly for citrus fruits, and the calculations were made on the basis of a maximum draft of 1 second-foot to 160 acres, or a duty of water with 80 per cent continuous operation of approximately 2.7 acre-feet per acre per annum.

[a] The cost 60 cents per 24 hours per useful water horsepower for fuel oil was assumed and from this the useful water horsepower and discharge were calculated. Two irrigations were given during the season, though three were considered desirable.

[b] The second line for test No. 25 relates to customary use of the plant; during the latter part of the test the engine was speeded up, giving the results shown in the first line without any material increase in fuel consumption.

[c] This is supplementary to a gravity supply utilized during the first half of the season.

[d] Proposed to irrigate in 1911. Plant installed late in season of 1910.

[e] Tests reported by owner.

[f] Used as supplement to gravity supply on 100 acres of this amount.

[g] Pump and motor on movable frame raised for the winter when test was made. The suction head was therefore very great and the quantity of water pumped much less than that supplied when the pump is in its normal position.

than is needed to supply the acreage watered the error can of course be remedied if more land can be furnished with water. The same result will of course be accomplished either by bringing new land under irrigation or by supplying from one plant lands that have been watered by two or more pumping units each of which has been operated only a small part of the time. The advantage of cooperation in reducing the cost per acre of irrigation is shown in the plants listed as tests Nos. 31 and 35.

Although theoretically the pumping system might be only large enough to furnish the necessary amount of water if kept running continuously throughout the irrigation season, practically the minimum size of plant is approximately fixed by the necessity of pumping a stream large enough to flow through the irrigation ditches with sufficient velocity to permit its proper distribution. From the observations made in San Joaquin Valley it would appear that in this region plants of less than 5 horsepower are not efficient in this respect, except perhaps in the case of plants used for watering small truck gardens. The size of stream that must be thrown in order to give proper distribution depends very largely on the character of the soil, however. In Sacramento Valley it has been found that "a discharge of at least 12 gallons a minute to the acre should if possible be provided for alfalfa on ordinary loam soils in tracts of 40 to 200 acres, with larger capacities for smaller tracts, and slightly smaller capacities for larger tracts."[1]

Although in some regions economy is obtained by the use of smaller plants pumping into reservoirs from which a sufficient discharge can be maintained during periods of irrigation, this practice has not been followed in the San Joaquin, and the cost of reservoir construction probably would more than counterbalance the saving in cost of pumping equipment under the conditions of irrigation that obtain.

In localities where pumping plants are installed as auxiliaries to surface water supplies the adaptation of proper size of plant to the area irrigated can not be adhered to; for in such instances a relatively large amount of water may need to be pumped during intervals of shortage in the ditch supply, and machinery capable of furnishing a given quantity of water in a limited time may be required. Such conditions obtain mainly in places where high-class crops are raised, however, which can profitably bear the relatively high cost per acre of pumping water. An example of this is furnished in the plant of W. E. Bunker (No. 15).

In connection with the mistake of installing a larger plant than is needed for the area irrigated may be mentioned the installation of a plant having greater pumping capacity than the well can supply.

[1] Bryan, Kirk, Ground water for irrigation in the Sacramento Valley, Cal.: U. S. Geol. Survey Water-Supply Paper 375-A, p. 38, 1915.

Considerable loss in efficiency may develop in such cases, either simply from excessive draw down, which makes the pumping lift greater than need be, or from the entrance of air into the pump, whose suction is thereby impaired. Losses of efficiency directly traceable to leakage of air were noted in tests Nos. 8 and 39. Such overtaxing can usually be overcome by enlarging the well or by sinking one or more auxiliary wells connected by tunnels or by suction pipes to the pump intake.

Although pumps in good condition may lift water about 28 feet under suction, a lift of about 20 feet has been found in practice to be the maximum economical limit. Centrifugal pumps and the cylinders of reciprocating pumps should therefore be placed not higher than this distance above the water level when pumping. Examples of low efficiency produced in part at least by excessive suction lifts are furnished by plants Nos. 8, 21, and 30. Enlargements or bellmouths on the ends of intake and discharge pipes are found to reduce the friction loss of head at entrance and discharge points and thus slightly to increase the efficiency. Likewise, the elimination of unnecessary elbows and bends in the pipes reduces friction losses. Cases where actual obstructions in pipes appeared to be responsible in part for the low efficiency were noted in plants Nos. 51 and 55.

At many pumping plants the end of the discharge pipe is placed higher than is necessary. Since every foot in height that the water is raised requires a certain amount of work, it is obvious that the discharge point should be only high enough to deliver the water into the ditch. Flagrant cases of disregard of this principle were not observed in the San Joaquin, however.

The running of a large internal combustion engine at less than its load capacity is an important factor in increasing pumping costs. Under such conditions, in order to keep down to normal speed, the engine misses a number of explosions each minute. Serious loss in efficiency may thus be occasioned, as brake tests show that under such conditions there is a marked loss in the effective work. This loss is due largely to the fact that the power consumed within the machine in compression of the charge and in friction losses is approximately constant, and hence as the amount of work produced by the machine is decreased the energy consumed internally becomes a larger portion of the total amount.[1] An especially noteworthy instance of low efficiency due to a poorly designed plant was found in that of T. R. Hill (test No. 1). The overloading of an engine, when normal speed is kept up by feeding an extra amount of fuel, is also uneconomical, both because of the excessive fuel consumption and the strain on the machinery.

[1] Le Conte, J. N., and Tait, C. E., Mechanical tests of pumping plants in California: U. S. Dept. Agr. Office Exper. Sta. Bull. 181, p. 72, 1907.

Notable variations in speed, either of increase or of decrease beyond the normal, result in inefficient service; for every properly constructed engine is designed to run under conditions of speed and load that are fairly well determined by the size of the engine parts, and any great variation in these conditions is bound to be attended by loss in efficiency from one or more causes. In electric motors underspeeding does not result in notable efficiency loss since the internal friction losses are slight and a large part (80 to 90 per cent) of the power consumed is given out as useful work. Overspeeding, however, may necessitate repairs due to the overheating or burning out of parts.

The proper adjustment of feed and ignition in an internal combustion engine have very great influence on the efficient working of the machine. If the ignition is retarded too much, an excessive fuel charge is required. By advancing the spark, therefore, to produce a certain amount of preignition, the fuel consumption may be cut down appreciably. The improper timing of ignition may have been the cause of excess fuel consumption in plants Nos. 18, 19, and 28.

The temperature of the jacket water is a factor that is too often overlooked; for if the cylinder is cooled too much, ignition may lag, and the same effect will be produced as by a spark too far retarded.

Too little attention is in many cases paid to the proper oiling and adjustment of the various bearings. Injury of course may quickly result to them from overheating due to lack of oil, or to running too tight, while if too much play is allowed the engine will become injured by pounding. Slippage of a loose belt is often the cause of poor service, as in tests Nos. 13 and 40, while too tight a belt produces an undue strain on the pulley bearings.

For proper running of a pump, relations of load and speed similar to those in an engine must be taken into consideration. The improper speeding of a centrifugal pump will cause loss in efficiency because if underspeeded the runner will not impart an economic proportion of its velocity to the water, and therefore the pump will not lift water to its full capacity (tests Nos. 1 and 27); or, because if overspeeded, the runners will churn or will produce excessive velocity in the stream of water, with consequent losses due to excessive friction in the intake and outlet pipes (test No. 5). While a centrifugal pump throws more water when somewhat overspeeded, it requires much more power for a given discharge than does a larger pump run at the proper speed. As has been previously mentioned, overspeeding may also cause marked drop in efficiency by drawing air into the pump and impairing its suction. Overspeeding is, however, less to be avoided than underspeeding, since the discharge drops rapidly with slower rotation.

For each rotary pump there is a definite relation between the lift of the water and the speed of the pump, for greatest efficiency. The proper speed for each lift is usually given by the pump maker, and should be closely adhered to for satisfactory results both in the amount of water lifted and in power economy.

In reciprocating pumps underspeeding may in some cases produce undue diminishing of the discharge through failure of the valves to open and close promptly. Overspeeding often results in the breaking of sucker rods or the loosening of pump foundations, with consequent throwing out of alignment and increased friction losses.

The proper size and speed for the pump will be determined by the amount of water to be discharged and the lift. The engine or motor should then be adapted in size to give the necessary power. By means of the proper-sized pulleys or gears the suitable working speed for both pump and prime mover can be obtained. The proper size of prime mover and pump for given lifts and discharge are given in some manufacturers' catalogues or will be supplied by the service departments of the firms. Consultation with these departments will often prevent costly mistakes in the installation of a plant. For the larger plants special design to suit the conditions of operation will generally be profitable. The following tables may be of use in some cases, however, in aiding in the choice of a suitable combination of prime mover and pump.

TABLE 35.—*Time required for irrigation with pumps of various sizes, assuming 3 acre-feet as duty of water per acre per annum.*

Area to be irrigated.	Water required per annum.	Time required for pump to raise tabulated quantities of water.[a]							
		3-inch pump, capacity 225 gallons per minute.	3½-inch pump, capacity 300 gallons per minute.	4-inch pump, capacity 400 gallons per minute.	5-inch pump, capacity 700 gallons per minute.	6-inch pump, capacity 900 gallons per minute.	7-inch pump, capacity 1,200 gallons per minute.	8-inch pump, capacity 1,600 gallons per minute.	10-inch pump, capacity 3,000 gallons per minute.
Acres.	*Acre-feet.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*
5	15	360							
10	30	720	542						
15	45	1,080	814	610					
20	60	1,420	1,080	814					
30	90	2,160	1,630	1,220	697	542			
40	120	2,880	2,170	1,630	930	723	542		
60	180	4,320	3,260	2,440	1,400	1,080	814	610	
80	240		4,340	3,260	1,860	1,440	1,080	814	
100	300			4,070	2,320	1,810	1,360	1,020	542
120	360			4,880	2,790	2,170	1,630	1,220	650
160	480				3,720	2,890	2,170	1,630	868
200	600				4,650	3,620	2,710	2,030	1,080
240	720					4,340	3,260	2,440	1,300
280	840					5,060	3,800	2,850	1,520
320	960						4,340	3,260	1,730
360	1,080						4,880	3,660	1,950
400	1,200							4,070	2,170
480	1,440							4,880	2,600
560	1,680								3,040
640	1,920								3,470
760	2,280								4,120
880	2,640								4,770

[a] Capacities taken from manufacturers' catalogues.

TABLE 36.—*Engine horsepower, cost of pumping plant, annual fixed charges, and cost per hour of operation for pumps operated against various static heads.*[a]

Static head.	Size of pump.	Engine horse-power.	Cost of pumping plant.	Annual fixed charges.	Cost per hour of operation.
Feet.	*Inches.*				*Cents.*
20	3	3	$300	$59	6.7
	3½	4	360	72	7.6
	4	5	420	85	9.1
	5	8	600	125	11.9
	6	10	770	162	13.4
	7	15	1,050	218	17.2
	8	20	1,320	274	22.2
	10	35	1,920	398	39.9
25	3	4	350	70	7.3
	3½	5	410	83	8.6
	4	6	480	99	10.1
	5	10	720	149	13.1
	6	15	990	205	16.2
	7	18	1,150	238	20.9
	8	25	1,480	307	27.3
	10	45	2,250	467	49.3
30	3	4	360	71	8.3
	3½	6	470	95	9.3
	4	8	590	121	10.5
	5	12	840	173	15.3
	6	18	1,110	229	18.8
	7	20	1,280	264	24.7
	8	30	1,660	343	32.4
	10	50	2,430	502	58.8
35	3	5	420	83	9.0
	3½	6	480	96	10.5
	4	8	600	122	11.9
	5	15	960	197	17.5
	6	18	1,120	230	21.9
	7	25	1,450	298	28.5
	8	35	1,840	379	37.4
	10	60	2,660	549	68.3
40	3	6	480	94	9.3
	3½	8	600	121	10.5
	4	10	720	146	12.1
	5	18	1,080	220	19.7
	6	20	1,230	251	24.7
	7	30	1,620	332	32.3
	8	40	2,010	413	42.4
	10	75	3,000	618	77.8
45	3	6	530	104	10.2
	3½	8	660	132	11.5
	4	10	790	159	13.4
	5	18	1,170	238	21.9
	6	25	1,500	306	27.6
	7	30	1,740	356	36.1
	8	45	2,300	472	47.5
	10	75	3,170	649	87.2
50	3	8	640	126	10.0
	3½	10	780	155	11.5
	4	12	910	182	14.6
	5	20	1,290	261	24.1
	6	25	1,510	307	30.4
	7	35	1,920	392	39.9
	8	50	2,470	506	52.5
	10	100	3,760	773	96.5
55	3	8	650	127	10.8
	3½	10	790	156	12.4
	4	15	1,030	206	15.9
	5	25	1,460	295	26.3
	6	30	1,690	343	33.3
	7	40	2,100	428	43.7
	8	50	2,480	507	57.8
	10	100	3,770	774	106.0
60	3	8	660	128	11.5
	3½	10	800	157	13.4
	4	15	1,040	207	17.2
	5	25	1,470	296	28.5
	6	30	1,700	344	36.1
	7	45	2,270	462	47.5
	8	60	2,710	553	62.8
	10	100	3,780	775	116.0

[a] Cost of pumping plant is exclusive of wells and casing. Fixed charges are 8 per cent of cost of pumping plant plus 14 per cent of cost of machinery. Cost of operation is cost of fuel at 10 cents a gallon plus 2 cents an hour for labor and lubrication.

From the average rated capacity for each size of pump, obtained from manufacturers' catalogues (Table 35), and the lift, the necessary water horsepower is obtained from the formula given on page 165, which may be a little more simply expressed thus:

$$\text{Useful water horsepower} = \frac{\text{Total static head in feet} \times \text{discharge in gallons per minute}}{3{,}957}$$

A plant efficiency of about 43 per cent, determined mainly from experimental tests of good plants, has been applied to these values of water horsepower to obtain the figures of required engine horsepower for Table 36, the nearest standard size of engine above the required horsepower being taken in nearly every case. The sizes of engine needed are larger than those given in similar tables in catalogues of pumping machinery; but they are believed, from results observed in actual experience, to be approximately correct.

The cost of pumping plant includes only the cost of engine, pump and fittings, and the housing. Since the cost of engine and pump varies somewhat according to the make and the cost of housing varies with the style of building used, the three items have been combined into the averages presented. The prices used for the machinery, however, are average list prices for the indicated sizes of distillate engines and centrifugal pumps, and the cost of housing is based on actual examples. This latter item is taken as about $50 for the smaller plants, increasing for the larger sizes by about 10 per cent of the additional cost of the machinery. Attempt has not been made to determine the average cost of well and casing, since these are such variable quantities that averages would be of no special significance. In some places the cost of the completed well is relatively small, while in other places it may equal the cost of the remainder of the plant.

The annual fixed charges have been computed as 8 per cent of the cost of pumping plant plus 14 per cent of the estimated cost of engine and pump alone. While this is a somewhat different basis of estimate from that used in calculating the fixed charges of Table 34, and includes allowance for interest and taxes, it is believed to be fair and to give approximately the same results.

The cost per hour of operation is based on the probable amount of distillate used per hour, at 10 cents per gallon, plus 2 cents per hour of operation for labor and lubrication. The duty of distillate is taken, as the result of numerous tests, at one-eighth gallon per horsepower per hour developed. In the table this is of course not the same as the horsepower "size" of the engine, which is adapted only approximately to the actual power required. The hourly consumption of distillate for each combination of pump and lift can be obtained, if desired, from the last column, by subtracting the labor

and lubrication cost (2 cents) and dividing by 10 (the assumed price in cents per gallon). For example, in the first case the computed distillate consumption is 0.47 gallon per hour. From this figure other calculations based on different costs per gallon can be made.

Example.—It is desired to irrigate by pumping a tract of 80 acres of land to be set in alfalfa. In consideration of rainfall, evaporation, and other climatic conditions the area should be flooded during the irrigation season with sufficient water in amount to cover the land 3 feet in depth (equivalent to flooding 6 inches in depth six times during the season). The depth to water in neighboring wells is about 20 feet, and it is desired to raise the water 5 feet above the surface of the ground at the proposed pumping plant. The irrigation season is about 200 days in length.

Referring to Table 35, opposite 80 in the first column, we find that a 3½-inch pump will require 4,340 hours, or 21.7 hours a day for 200 days to supply the desired amount of irrigating water; a 4-inch pump will require 3,260 hours, or 16.3 hours a day for 200 days; a 5-inch pump will require 1,860 hours, or 9.3 hours a day for 200 days; a 6-inch pump will require 1,440 hours, or 7.2 hours a day for 200 days, etc. Now, the depth to water being 20 feet and the lift above the surface of the ground 5 feet, a head of 25 feet must be provided for in addition to the suction lift. The suction lift should be taken at 25 feet unless it be known that a well of great capacity can be secured. The total static head, therefore, in this case will be 50 feet. In the table on page 173, opposite "50" in the column for static head, the following information can be found:

a. 3½-inch pump, 10-horsepower engine, cost, with housing, $780:	
Fixed charges	$155
Operation, 4,340 hours at 11.5 cents per hour	499
Total yearly cost of pumping	654
Yearly cost per acre	8.18
b. 4-inch pump, 12-horsepower engine, cost, with housing, $910:	
Fixed charges	182
Operation, 3,260 hours at 14.6 cents per hour	476
Total yearly cost of pumping	658
Yearly cost per acre	8.22
c. 5-inch pump, 20-horsepower engine, cost, with housing, $1,290:	
Fixed charges	261
Operation, 1,860 hours at 24.1 cents per hour	448
Total yearly cost of pumping	709
Yearly cost per acre	8.86
d. 6-inch pump, 25-horsepower engine, cost, with housing, $1,510:	
Fixed charges	307
Operation, 1,440 hours at 30.4 cents per hour	438
Total yearly cost of pumping	745
Yearly cost per acre	9.31

e. 7-inch pump, 35-horsepower engine, cost, with housing, $1,920:

Fixed charges	392
Operation, 1,080 hours at 39.9 cents per hour	431
Total yearly cost of pumping	823
Yearly cost per acre	10.29

It appears from these figures that the total cost of pumping gradually increases with the size of plant used. This is because the larger plants lie idle a proportionately greater time, while interest, taxes, depreciation, etc., accumulate. With the foregoing information in mind, the rancher can proceed to have a well, or wells, bored with some definite idea of the sort of plant he will need. The boring, digging, or drilling of wells in such manner as to secure the greatest flow of water at least cost is a matter subject to wide variation in procedure in accordance with local conditions. Let it be assumed that a well is bored and the test [1] shows a flow of 300 gallons a minute with a lowering of 15 feet in the water surface. Such a well will supply a $3\frac{1}{2}$-inch pump with a suction lift of 15 feet (assuming the pump to be placed at the water surface); a 4-inch pump with a suction lift of about 20 feet; but will not supply a pump of larger size. With this well, therefore, the choice is narrowed down to plants *a* and *b*. It is now possible to revise the estimates because, instead of a suction lift of 25 feet, as previously assumed, it is known that the lift will be about 15 feet for plant *a*, or 20 feet for plant *b*. The total static heads will be 40 feet and 45 feet, respectively. From Table 36 the following revised estimates are derived:

a–1. 40-foot head, $3\frac{1}{2}$-inch pump, 8-horsepower engine, cost, with housing, $600:

Fixed charges	$121
Operation, 4,340 hours at 10.5 cents per hour	456
Total yearly cost of pumping	577
Yearly cost per acre	7.21

b–1. 45-foot head, 4-inch pump, 10-horsepower engine, cost, with housing, $790:

Fixed charges	159
Operation, 3,260 hours at 13.4 cents per hour	437
Total yearly cost of pumping	596
Yearly cost per acre	7.45

It is seen that plant *b*–1 costs $190 more than plant *a*–1 and that the yearly cost of pumping will be $19 greater. In view of the lesser time required for pumping, the larger plant would probably be chosen by most ranchers, but with the foregoing study of the problem, the choice could be made intelligently with clear knowledge as to what the added convenience of the larger plant will cost. If a still larger plant were, for any reason, considered desirable additional wells would be required.

[1] Every well should be carefully tested by pumping and its flow measured before a pumping plant is purchased. Only in this way can the plant purchased be adapted to the flow obtainable from wells.

COUNTY NOTES.

By W. C. Mendenhall and R. B. Dole.

SAN JOAQUIN COUNTY.

GENERAL CONDITIONS.

San Joaquin County is, with the exception of small areas in Alameda and Contra Costa, the northernmost of those counties whose valley lands belong to the southern division of the great central lowland of California. Because of its latitude and its position near the gateway that opens to the Pacific, it differs greatly climatically from the southern counties of the valley. Its temperatures are not so high and do not fluctuate through so wide range (monthly averages vary from 46.5° in January to 72.5° in July and August), its rainfall is greater, amounting to about 15.5 inches, and its percentage of foggy days exceeds that of Kern, Tulare, and other of the southern counties. Furthermore, situated as it is along the lower San Joaquin, it includes a tidal section of that stream and a large area, called Stockton Islands, that is subject to inundation when the Sacramento is in flood, and a still larger section subject to overflow, except where it is protected by dikes and levees, when floods in the San Joaquin and its tributaries occur at the same time as those of the Sacramento. The county, therefore, includes a part of that central California area, whose problems of reclamation, drainage, and navigation involve in so complete and fascinating a way all of the phases of hydraulic engineering. The rivers must be improved and controlled for navigation purposes, the lowlands must be protected from floods and drained, while the higher bordering parts of the valley lands, too dry to produce the more valuable crops although suited to grain raising, require irrigation for their fullest development. This threefold problem belongs typically to the Sacramento Valley, but it requires solution also in that of the lower San Joaquin.

The Stanislaus Water Co. takes its supply of water from the Stanislaus near Knights Ferry and irrigates an area of several thousand acres along the southern border of the county in the Escalon and Manteca districts. In the Lodi and Stockton districts the systems of the Stockton & Mokelumne Irrigating Co. and the Woodbridge Canal & Irrigation Co. supply surface waters to limited areas. Within the island district, west and north of Stockton, where reclamation has been accomplished by the construction of protective levees, water is

sometimes admitted within the dikes during high-water periods in the streams for irrigation purposes, but as subirrigation is effectual throughout the greater part of these areas, surface irrigation is rarely necessary.

The higher lands of the valley slopes, both along the east and west sides, are devoted to grain raising, as some of them have been for almost half a century. No water is applied to them. There is no uniformity as to practice among the vineyardists, some of them irrigating their vines, others preferring that they be not irrigated.

FLOWING WELLS.

San Joaquin County includes the northern portion of the great central artesian zone of the valley, but as this zone is less important in its northern part, both because of the inferior yield of wells there and because of the greater proportion of water of poor quality obtained from them, there has been relatively little development for irrigation purposes or domestic supply. Twenty-nine records have been obtained, and these are believed to include all of the flowing wells existing in the country districts and nearly all of those in the city of Stockton at the time when the records were secured. Only six of these supply water suitable for irrigation, and the yield of these is small. By far the greater number of the flowing wells have been drilled for the gas they yield, but as the water with the gas is saline and therefore not usable for drinking or for irrigation it is allowed to waste.

The few artesian wells that furnish water of good quality not only yield small supplies but are expensive because of their considerable depth. Those of which records are available are from 975 to 1,200 feet deep. Wells of lesser depth do not yield flows, and those of greater depth, at least in the Stockton neighborhood, yield saline waters and gas. Farther west than Stockton, nearer the axis of the valley, the water, even from shallow wells, is strongly mineralized. It will be realized that under these conditions flowing wells are not of value for irrigation in the county, despite the rather large area over which flows may be obtained.

PUMPING PLANTS.

During the last few years irrigation by the use of pumped waters has become an important factor in the development of the east side of San Joaquin County. Around Lathrop and French Camp in the district east of Stockton and in the country about Lodi, a large number of plants have been installed and new wells are being sunk and new plants put in operation constantly.

This development is of a most promising type. Most of the plants are small and the acreage irrigated by each is limited. This means small holdings, intensive cultivation, and eventually relatively dense settlement. The average recorded horsepower of 193 plants is only 6.2. Of the 193 plants 138 develop from 2 to 8 horsepower, while 42 are equipped with engines developing from 10 to 15 horsepower. One hundred and eighty-seven gas engines were in use in 1906, 13 plants used motors at that time, and 2 were operated by steam.

One hundred and thirty-seven owners of plants reported a total of 1,455 acres under irrigation, an average of only 10.6 acres each. The cost of 106 of the plants was reported by the owners as $64,983, an average cost of $613 each. These facts indicate the small scale and individualistic character of the development.

The power companies charge a uniform rate of 3⅓ cents per horsepower per hour. This is higher than the fuel charge in the gas plants, the reported average in 12 plants for the summer of 1906 being 1.45 cents per horsepower per hour, but labor and installation, both of which are heavier charges in the gas plants, tend to equalize the difference. Water as developed in these small plants seems to cost the users from $1.50 to as much as $3 or $4 per acre-foot.

Generally water is delivered from the pumping plants to the acreage served through earth ditches, and where the soil is sandy and porous this method results in much waste.

The pumping-plant wells are comparatively shallow, and hence are very much cheaper than the deep wells necessary to secure artesian flows. The average depth of somewhat more than 100 wells, taken at random from the records, is about 80 feet. Another group of 20 wells average only 40 feet in depth. These latter wells are equipped with small pumping plants, developing an average of 5 horsepower each, and the water which they yield is ample.

The wells are particularly cheap because it has been found that in many parts of the area it is not necessary to case them, or at least they need be cased only to slight depths. Twelve pumping-plant wells are reported as without any casing; 24 others were only partly cased, the pipe in these varying in length from a few joints to three-fourths or seven-eighths of the entire depth of the well.

The windmill has been an important factor in irrigation in the Stockton district, and although it has been practically superseded by the small pumping plant, it is still used, especially in the vegetable garden and fruit districts east and northeast of Stockton. Its chief disadvantage, of course, is the uncertainty of the wind. It is not unusual to see a well equipped both with a small gas engine and a large windmill, the engine being used when the wind fails. The wheels used are of wood and of local manufacture, from 18 to 22 feet in diameter, and cost complete with the tower from $175 to $200.

Much of the gardening and fruit for the San Francisco market is in the hands of Italian immigrants, who, after giving the windmill a thorough trial, have generally abandoned it in favor of the more reliable gas engine.

Irrigation by pumping, of the general type practiced about Stockton and Lodi, could be extended with great advantage throughout a large acreage, now without water, between Mokelumne River and Tejon Pass, but to be practiced successfully it will require a different spirit from that which as yet largely dominates the West. The promoting and speculative spirit, the desire to get rich overnight, to control large holdings, and to avoid personal labor, will have to be superseded by a willingness to be satisfied with sure but moderate returns, to be content with small farm units, and to attain personal independence through individual effort. It is to be hoped that the American citizen of the generations to come will prove willing to accept these conditions and that in the future dependence need not be placed upon our adopted citizens for detailed development of this desirable type.

QUALITY OF WATER.

The waters that were tested from wells 20 to 40 feet deep on the east side of San Joaquin County contain somewhat greater quantities of all mineral constituents than those from wells 50 to 1,100 feet deep, and though they are low in alkalies and are good for irrigation they are rather poor for steaming because of their content of scale-forming matter. Water from wells 50 to 900 feet deep is commonly the best. Wells around Stockton 900 to 1,100 feet deep yield water somewhat higher in sodium and potassium than in calcium and magnesium and therefore poorer for irrigation; this characteristic content of alkali probably decreases, however, toward the Sierra. Waters from depths greater than 1,100 feet around Stockton are unfit for use because they are salty, and that condition probably is uniform over the entire county.

No ground waters among Stockton Islands could be tested, but according to common report they are bad, which doubtless means that they are highly mineralized calcium sulphate or sodium sulphate waters with appreciable amounts of chlorides. This would make them bad for boilers and poor for irrigation.

The waters of T. 2 S., R. 4 E., are higher in mineral content and poorer for irrigation than those farther east, and many are of the calcium sulphate type. Around Tracy and Banta wells more than 100 feet deep yield better water than shallower ones. The change to waters of the axial type, or those in which the alkalies exceed the alkaline earths, is apparently complete within the limits of El Pescadero, where the waters that were tested are suitable for irrigation. Water

				tion.	
Sou	High	$Na\text{-}SO_4$	Bad	Fair	Southern Pacific Co.
Pac	do	$Ca\text{-}SO_4$	do	do	Pacific Coast Oil Co.
Sou	Moderate	$Na\text{-}SO_4$	Poor	Good	Southern Pacific Co.
	do	$Ca\text{-}SO_4$	do	do	Do.
	Low	$Ca\text{-}CO_3$	Fair	do	Do.
	Moderate	do	do	do	Do.
A.	do	do	do	do	F. M. Eaton.
Sou	do	do	do	do	Southern Pacific Co.
Dr.	do	do	do	do	F. M. Eaton.
F.	do	do	do	do	Do.
Sto	Very high	$Na\text{-}Cl$	Very bad	Bad	Do.
Sar	Moderate	$Na\text{-}CO_3$	Poor	Fair	Kennicott Water Softener Co.
Sto	do	do	Fair	do	Walton Van Winkle.
	do	do	do	do	F. M. Eaton.
	do	do	do	do	D. B. Bisbee.
Sou	do	$Ca\text{-}CO_3$	do	Good	Southern Pacific Co.
Sai	do	do	do	do	F. M. Eaton.
W.	do	do	Poor	do	Southern Pacific Co.
Sou	do	do	do	Fair	Do.
	do	do	Fair	Good	Do.
J.	do	do	do	do	F. M. Eaton.
Sa	do	do	do	do	Kennicott Water Softener Co.

deep.
ımping station.
)0 feet deep.
,000 feet deep.

TABLE 37.—*Field assays of ground waters in San Joaquin County.*

[Parts per million except as otherwise designated.]

Owner.	Date, 1910.	Location.			Depth of well (feet).	Determined quantities.					Computed quantities.					Classification.			
		Sec.	T.	R.		Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total solids.	Scale-forming ingredients (s).	Foaming ingredients (f).	Probability of corrosion (c).	Alkali coefficient (k) (inches).	Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.
Pacific Coast Oil Co.	Sept. 28	13	2 S.	4 E.	468	Tr.	156	344	110	371	850	400	350	?	16	High	$Na-SO_4$	Bad	Fair.
Mrs. Coogan	..do	22	2 S.	4 E.	200	3	145	955	400	786	2,200	820	1,200	C.	4	Very high	..do	Very bad	Do.
T. H. Henderson	..do	22	2 S.	4 E.	160	Tr.	231	785	555	666	2,300	700	1,500	?	3	..do	..do	..do	Do.
H. Boltzen	..do	28	2 S.	4 E.	455	Tr.	178	865	305	677	2,000	710	1,100	C.	6	High	..do	..do	Do.
J. G. Clark	..do	32	2 S.	4 E.	46	Tr.	198	505	130	606	1,200	640	350	?	14	..do	$Ca-SO_4$	Bad	Do.
J. A. Cordes	..do	34	2 S.	4 E.	93	0	163	138	45	238	450	270	140	?	40	Moderate	..do	Poor	Good.
P. Smith	..do	22	2 S.	5 E.	45	3	213	530	175	563	1,300	600	570	C.	10	High	$Na-SO_4$	Very bad	Fair.
John Brush	Sept. 29	24	2 S.	5 E.	20	0	182	238	110	361	720	400	200	C.	17	..do	$Ca-SO_4$	Poor	Do.
Southern Pacific Co.	Sept. 28	28	2 S.	5 E.	157	0	188	150	50	225	500	250	220	?	30	..do	$Na-SO_4$	..do	Good.
Do.	..do	28	2 S.	5 E.	300	Tr.	164	104	40	193	410	220	140	?	45	Moderate	$Ca-SO_4$	..do	Do.
J. Rathaen	Sept. 29	36	2 S.	5 E.	110	0	146	208	85	293	600	320	220	C.	20	High	..do	..do	Do.
A. S. Laselle	Oct. 2	25	3 N.	6 E.	(a)	0	121	Tr.	20	111	190	160	30	N. C.	100	Moderate	$Ca-CO_3$	Fair	Do.
George Swain	..do	12	2 N.	6 E.	180	0	166	10	45	241	880	290	5	?	45	..do	..do	Poor	Do.
F. A. West	..do	Campo de los Franceses			237	0	121	Tr.	10	84	170	130	40	N. C.	55	..do	..do	Fair	Do.
Mrs. Julia Weber	..do	..do			52	0	272	10	25	263	340	300	10	N. C.	80	..do	..do	Poor	Do.
S. Sanguinetti	..do	..do			1,162	9	242	Tr.	15	19	300	70	300	N. C.	6	..do	$Na-CO_3$	Bad	Fair.
San Joaquin County	..do	..do			38	Tr.	200	10	15	188	200	240	10	N. C.	140	..do	$Ca-CO_3$	Poor	Good.
E. M. Oren	Sept. 19	Stockton			40	0	219	20	115	212	430	240	200	?	18	..do	$Na-CO_3$	..do	Fair.
Stockton Water Co.	..do	..do			(b)	6	205	5	90	44	390	70	360	N. C.	6	..do	..do	Bad	Do.
Do.	Sept. 18	..do			(c)	0	233	10	65	68	370	120	310	N. C.	7	..do	..do	..do	Do.
Citizens Gas Co.	Sept. 19	..do			1,786	0	94	5	2,865	250+	4,700	......	5,000	C.	.6	Very high	Na-Cl	Very bad	Bad.
Stockton Gas & Electric Co.	..do	..do			2,500	0	78	5	4,110	1,838	6,800	1,900	5,400	C.	.5	..do	..do	..do	Do.
Dr. Asa Clark	..do	..do			70	0	445	46	212	250+	800	......	......	N. C.	10	High	$Ca-CO_3$		Fair.
Do.	..do	..do			200	Tr.	148	5	20	94	220	140	80	N. C.	30	Moderate	..do		Good.
Joseph Yettner	..do	Campo de los Franceses			70	Tr.	138	5	20	90	210	140	80	N. C.	30	..do	..do	Fair	Do.
W. S. Moss estate	..do	..do			40	Tr.	130	5	10	83	190	130	50	N. C.	45	..do	..do	..do	Do.
Lorenzo Hurd	..do	..do			213	Tr.	153	5	15	105	210	150	70	N. C.	35	..do	..do	..do	Do.
W. E. Court	Sept. 30	..do			100	0	107	5	10	72	160	120	50	N. C.	55	Low	..do	..do	Do.
Elwood Varney	..do	24	1 S.	6 E.	......	Tr.	260	25	105	286	400	340	140	?	10	Moderate	..do	Poor	Do.
D. A. Sanguinetti	..do	26	1 S.	6 E.	114	0	148	5	20	111	220	160	50	N. C.	60	..do	..do	Fair	Do.
Ruell C. Nelson	..do	3	2 S.	6 E.	40	0	33	5	15	33	110	80	20	?	140	Low	..do	Good	Do.
Jacob Rhodes	Sept. 29	30	2 S.	6 E.	52	Tr.	201	265	165	493	800	520	240	C.	12	High	$Ca-SO_4$	Bad	Fair.
New Jerusalem schoolhouse	Oct. 6	18	3 S.	6 E.	124	3	214	181	55	258	580	300	250	?	30	..do	..do	Poor	Good.
L. Gerlach	..do	El Pescadero (Grimes)			80	Tr.	188	96	30	220	400	250	110	?	55	Moderate	$Ca-CO_3$	..do	Do.
Jacob Ohm	..do	..do			120	Tr.	213	132	35	229	460	260	180	?	40	..do	..do	..do	Do.
John Tretheway	Oct. 3	11	4 N.	7 E.	137	0	161	Tr.	40	171	250	200	20	?	50	..do	..do	..do	Do.
Henry Pope	Oct. 2	6	3 N.	7 E.	90	0	117	Tr.	20	90	180	140	50	N. C.	65	..do	..do	Fair	Do.
S. B. Light	Sept. 20	11	2 N.	7 E.	......	0	426	30	140	341	670	370	320	N. C.	11	High	..do	..do	Do.
E. E. Gerlach	..do	24	2 N.	7 E.	27	0	240	10	35	222	330	270	50	?	60	Moderate	..do	Bad	Fair.
A. Sanguinetti	..do	Campo de los Franceses			40	0	219	10	15	192	280	240	20	N. C.	140	..do	..do	Poor	Good.
Mrs. S. Boiliger	..do	1	1 N.	7 E.	100	0	219	5	35	195	300	250	50	N. C.	60	..do	..do	..do	Do.
W. G. Smith	Oct. 4	25	1 N.	7 E.	98	0	138	Tr.	35	148	220	200	20	?	60	..do	..do	..do	Do.
San Joaquin County	..do	27	1 N.	7 E.	40	0	214	5	45	210	310	260	50	?	45	..do	..do	Fair	Do.
Michael Early	..do	28	1 N.	7 E.	80	0	158	5	130	286	400	320	40	?	16	..do	..do	Poor	Do.
Theo. Infelt	Sept. 20	Campo de los Franceses			64	0	169	5	30	174	250	220	20	?	70	..do	Ca-Cl	..do	Fair.
George Barbero	..do	..do			130	0	129	Tr.	10	117	190	170	10	N. C.	200	..do	$Ca-CO_3$	..do	Good.
Theo. Kneppe	..do	..do			150	0	223	15	30	208	310	200	40	?	70	..do	..do	Fair	Do.
R. Junger	..do	..do			1,010	Tr.	131	Tr.	35	14	220	60	190	N. C.	10	..do	..do	Poor	Do.
C. T. Wiggin	Sept. 30	19	1 S.	7 E.	......	0	220	10	50	188	340	240	100	N. C.	40	..do	$Na-CO_3$	Fair	Fair.
Burdett Salmon	Sept. 19	Campo de los Franceses			1,200	0	151	5	1,735	912	3,000	950	2,200	C.	1.2	Very high	Na-Cl	Very bad	Bad.
Joe Wille	Oct. 6	27	2 S.	7 E.	80	3	192	10	50	186	320	240	80	N. C.	40	Moderate	$Ca-CO_3$	Poor	Good.
Mrs. Frank Hutchinson	..do	35	2 S.	7 E.	35	6	204	10	85	250	440	280	140	N. C.	25	..do	..do	..do	Do.
L. A. Gremaux	Sept. 20	7	2 N.	8 E.	40	0	258	Tr.	45	228	340	280	60	N. C.	45	..do	..do	..do	Do.
A. Roggi	..do	7	2 N.	8 E.	68	0	195	Tr.	15	174	240	220	10	N. C.	140	..do	..do	..do	Do.
G. H. Grupe	..do	30	2 N.	8 E.	70	0	178	Tr.	25	141	240	190	60	N. C.	50	..do	..do	Fair	Do.
J. Uriell	Oct. 4	33	1 N.	8 E.	93	0	115	Tr.	15	82	170	130	50	N. C.	55	..do	..do	..do	Do.
G. W. Mourey	..do	3	1 S.	8 E.	18	0	105	Tr.	35	148	200	200	0	?	60	..do	..do	..do	Do.
B. F. Hardin	..do	15	1 S.	8 E.	67	0	89	Tr.	20	88	160	140	20	N. C.	100	..do	..do	..do	Do.
Louis Cook	..do	28	1 S.	8 E.	60	0	117	Tr.	25	112	190	160	20	N. C.	80	..do	..do	..do	Do.
G. B. Matthews	Oct. 5	20	2 S.	8 E.	42	Tr.	122	Tr.	15	90	180	140	40	N. C.	65	..do	..do	..do	Do.
J. S. Moulton	Oct. 6	20	2 S.	8 E.	128	Tr.	136	Tr.	15	151	190	200	0	?	140	..do	..do	..do	Do.
	Oct. 5	......	......	......	40	Tr.	268	5	45	215	300	250	100	N. C.	35	..do	..do	Poor	Do.
	..do	30	2 S.	8 E.	40	Tr.	223	5	55	204	340	250	80	N. C.	35	..do	..do	..do	Do.

[a] 3 wells 90, 90, and 218 feet deep. [b] 4 wells 665 to 975 feet deep. [c] 11 wells 200 to 1,100 feet deep.

TABLE 38.—*Mineral analyses of ground waters in San Joaquin County.*

[Parts per million except as otherwise designated.]

Owner.	Date.	Location.			Depth of well (feet).	Determined quantities.										Computed quantities.				Classification.				Analyst.
		Sec.	T.	R.		Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Scale-forming ingredients (s).	Foaming ingredients (f).	Probability of corrosion (c).[a]	Alkali coefficient (k) (inches).	Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.	
Southern Pacific Co.	Jan. —, 1899	28	2 S.	5 E.	86	[b] 36	......	65	30	131	0	158	268	118	726	280	350	?	15	High	$Na-SO_4$	Bad	Fair	Southern Pacific Co.
Pacific Coast Oil Co.	......	28	2 S.	5 E.	478	(c)	......	64	46	107	0	203	252	106	794	300	290	C.	17	..do	$Ca-SO_4$	..do	..do	Pacific Coast Oil Co.
Southern Pacific Co.	May —, 1899	28	2 S.	5 E.	390	[b] 31	......	55	21	81	0	164	170	61	497	230	220	?	28	Moderate	$Na-SO_4$	Poor	Good	Southern Pacific Co.
Do.	Sept. —, 1910	28	2 S.	5 E.	118, 396	[b] 24	......	55	19	63	0	189	115	53	421	220	170	?	33	..do	$Ca-SO_4$	..do	..do	Do.
Do.	July —, 1900	33	4 N.	6 E.	97	[b] 65	......	17	8	6	0	87	4	8	151	130	15	N. C.	400	Low	$Ca-CO_3$	Fair	..do	Do.
	May 4, 1908	1	3 N.	6 E.	......	[b] 60	......	28	11	26	0	130	7	36	236	160	70	N. C.	60	Moderate	..do	..do	..do	Do.
A. S. Laselle	Oct. 2, 1910	25	3 N.	6 E.	90, 90, 218	......	1.75	27	11	[d] 8	0	133	0	15	210	150	20	N. C.	140	..do	..do	..do	..do	F. M. Eaton.
Southern Pacific Co.	May, 1900	25	1 S.	6 E.	160	[b] 47	......	28	7	33	0	158	9	21	223	140	90	N. C.	30	..do	..do	..do	..do	Southern Pacific Co.
Dr. Asa Clark	Sept. 19, 1910	Campo de los Franceses.			200	......	.14	23	9.2	[d] 31	0	164	1.6	19	200	135	80	N. C.	27	..do	..do	..do	..do	F. M. Eaton.
F. A. West	Oct. 2, 1910	..do			237	......	.85	18	8.6	[d] 18	0	134	0	5.9	180	115	50	N. C.	40	..do	..do	..do	..do	Do.
Stockton Gas & Electric Co.	Sept. 19, 1910	Stockton			2,500	......	.35	742	224	[d] 1,550	0	86	0	4,310	7,489	2,590	4,200	C.	.5	Very high	Na-Cl	Very bad	Bad	Do.
Santa Fe Ry. Co.	Oct. 1, 1902	..do			(e)	[b] 54	......	9	4	103	0	215	4	55	335	90	280	N. C.	8	Moderate	$Na-CO_3$	Poor	Fair	Kennicott Water Softener Co.
Stockton Water Co.	Oct. 1, 1910	..do			(f)	57	.03	6.1	7.2	89	0	210	7.1	35	306	90	240	N. C.	9	..do	..do	Fair	..do	Walton Van Winkle.
Do.	Sept. 18, 1910	..do			(g)	......	.12	17	7.0	[d] 86	0	205	0	64	350	90	230	N. C.	10	..do	..do	..do	..do	F. M. Eaton.
Do.	Dec. 3, 1904	..do			(h)	[b] 48	......	23	11	84	0	242	5	59	349	130	230	N. C.	11	..do	..do	..do	..do	D. B. Bisbee.
Southern Pacific Co.	Apr. —, 1901	..do			199, 228	[b] 59	......	15	8	28	0	118	8	18	194	115	75	N. C.	35	..do	$Ca-CO_3$	..do	Good	Southern Pacific Co.
San Joaquin County	Sept. 20, 1910	Campo de los Franceses.			40	......	.50	41	15	[d] 18	0	210	7.8	17	285	200	45	N. C.	70	..do	..do	..do	..do	F. M. Eaton.
W. B. Reiney	Sept. 12, 1910	23	4 N.	8 E.	......	[b] 84	......	33	24	20	0	185	10	45	306	220	55	?	45	..do	..do	Poor	..do	Southern Pacific Co.
Southern Pacific Co.	July —, 1900	30	4 N.	8 E.	30	[b] 47	......	46	31	75	0	202	28	112	468	240	200	?	18	..do	..do	..do	Fair	Do.
Do.	May —, 1900	36	2 N.	8 E.	42	[b] 60	......	16	9	10	0	71	2	28	160	120	30	?	75	..do	..do	Fair	Good	Do.
J. S. Moulton	Oct. 5, 1910	20	2 S.	8 E.	128	......	.50	38	12	[d] 0	0	149	0	15	225	180	0	?	140	..do	..do	..do	..do	F. M. Eaton.
Santa Fe Ry. Co.	Oct. 15, 1902	4	2 S.	9 E.	......	[b] 56	......	22	7	16	0	102	4	21	170	130	45	N. C.	100	..do	..do	..do	..do	Kennicott Water Softener Co.

[a] C., corrosive; N. C., noncorrosive; ?, corrosion uncertain or doubtful.
[b] Including oxides of iron and aluminum.
[c] Organic and volatile matter, 119 parts.
[d] Computed.
[e] Artesian well; probably more than 900 feet deep.
[f] Four wells 665 to 975 feet deep at electric pumping station.
[g] Eleven wells at pumping station, 200 to 1,100 feet deep.
[h] Fourteen wells at pumping station, 800 to 1,000 feet deep.

from wells 100 to 500 feet deep in the territory from El Pescadero to within 2 or 3 miles of the foothills could probably be applied to crops without harm if proper drainage were arranged, but water from wells more than 500 feet deep would probably be no better than that from shallower ones.

Though the water of San Joaquin River is altered in quality by the combined effects of ground affluents from the upper west side, seepage from irrigated lands on the east side, and occasional influxes of water from west-side creeks, it is usually low in mineral content and fairly clear, and at all times good for irrigation as the analyses made by the Geological Survey for two years establish.

The results of analyses and assays of ground waters in San Joaquin County are given in Tables 37 and 38, in which the waters have also been classified with respect to their value for domestic and boiler use and for irrigation.

WELL RECORDS.

The facts assembled in the following tables and in much of the preceding discussion were secured by W. N. White in 1906–7. Practically all of the pumping plants and all wells of importance then existing were examined and the essential data regarding them were secured. In addition enough of the shallow domestic wells in the outlying areas were examined to furnish evidence of the depth to ground water and to give some indication of its quality. Much more complete evidence on the latter point was procured by R. B. Dole in 1910 and has been assembled in the chapter and tables prepared by him and appearing both in the county notes and in the general discussion. Records of a few wells in Alameda, Calaveras, and Contra Costa counties are appended.

TABLE 39.—*Records of wells in San Joaquin, Contra Costa, Calaveras, and Alameda counties.*

San Joaquin County.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.[a]	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	*° F.*			*Miner's inches.*		
Lockeford village	Sec. 25, T. 4 N., R. 7 E.	1880?	Dug	60	42		Gas	D	b 3		$225
S. Parker	Sec. 36, T. 4 N., R. 7 E.	Old.	Bored, 7 inches	50	30		Wind	D, S.			
J. Ryan	Sec. 35, T. 4 N., R. 7 E.	1881?	Dug, 4 feet	42	31		do	D, S.			
D. J. Thomas	Sec. 5, T. 3 N., R. 8 E.	1887?	do	55	42	68	do	S.			
C. L. Jones	Sec. 8, T. 3 N., R. 8 E.	1886	Bored, 7 inches	85	34		do	D, S.			
D. J. Thomas	Sec. 17, T. 3 N., R. 8 E.	1875?	Dug and bored	82	33		do	D, S.			
Peters estate	Sec. 29, T. 3 N., R. 8 E.	Old.	do	60	30		do	D, S.			
W. L. Irvin	Sec. 32, T. 3 N., R. 8 E.	1906	Bored, 8 inches	224							
Do	do	1906	do	200	29?		Gas	I			1,800
Felix Faber	Sec. 3, T. 3 N., R. 7 E.	1904	Bored, 10 inches	50	24		do	I		$100.00	390
George Pressler	do		do	75	22		do	I			575
Peter Heil	Sec. 4, T. 3 N., R. 7 E.		Bored	80	10		do	I	b 75	100.00	600
L. M. Lewis	do	1904	Bored, 10 inches	86	22		do	I	b 40	140.00	550
J. C. Kennison	Sec. 5, T. 3 N., R. 7 E.	1904	Bored, 12 inches	45	15		do	I			c 575
P. Milloglav	do	1898	Dug and bored	46	15		do	I	b 45		c 1,200
A. H. Boese	do	1904?	Bored, 10 inches		15		do	I	b 40		425
H. D. Binger	do		Bored, 8 inches	85	16		do	I		75.00	650
J. C. Theden	do	1902	Bored	35	18		do	I	b 50	50.00	600
Mr. Olmar	Sec. 6, T. 3 N., R. 7 E.		Bored, 8 inches	66	15		Electric	I			
H. E. Taylor	do		Bored, 4 inches	70	15		do	I	b 17		325
Henry Pope	do	1903	Bored, 10 inches	90	16		do	I		110.00	175
G. O. Thornton	do		Bored, 8 inches	42	16		Gas	I	b 55		c 500
Levi Atwood	do		Bored, 10 inches	32	10		Electric	I			c 500
C. A. Black	do	1904	Bored, 8 inches	55?	12		Gas	I	b 20		400
Joe Williams	do		do	40	9.9	66	do	I			425
Joseph Moran	do		Bored, 12 inches	120	19		Electrical	I			700
Carey Bros	Lodi	1904	Bored, 8 inches	160	16		do	D			
Do	do	1904	do	160	16		do	D	b 130		
Mrs. J. L. Pearson	Sec. 13, T. 3 N., R. 6 E.	1904	Bored	85	13	66	Gas	I			506
M. C. Gammon	Sec. 12, T. 3 N., R. 6 E.	1902	Bored, 8 inches	44	4		do	I			c 700
E. E. Durston	do	1907	Bored, 6 inches	40	6		Electric	I		50.00	300
Ida Hill	do	1904	Bored, 8 inches	40?	8		Gas	I			c 300+
S. P. Howe	do	1904	Bored, 10 inches	80	8		do	I	b 20		285
Henry Adams	do	1906		36	7		Electric	I			300
N. F. Dethlefsen	do	1906	Bored, 6 inches	50	7		do	I			c 300
Paul Sturla	do	1904	Bored, 8 inches	100	7		Gas	I	b 55		

a D, domestic; S, stock; I, irrigation; B, boilers; N, not used; R, roads.
b Yield estimated or statement of owner taken.
c Cost of well and equipment combined.

TABLE 39.—*Records of wells in San Joaquin, Contra Costa, Calaveras, and Alameda counties*—Continued.

San Joaquin County—Continued.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	° *F.*			*Miner's inches.*		
Edward Hutchins	Sec. 2, T. 3 N., R. 6 E.						Electric	I			
Mrs. D. E. Allison	Sec. 11, T. 3 N., R. 7 E.	1903		27?	5	68	Gas	I	*a* 60		
C. D. Smith	Sec. 2, T. 3 N., R. 7 E.	1905	Dug and bored, 8 inches.	58	6		do	I			$225
G. De Pauli	Sec. 11, T. 3 N., R. 7 E.			34	6?		do	I			
T. B. Giffroy	do		Bored, 8 inches	35	5.5		Electric	I	*a* 20	$25.00	250
Charles Kraft	Sec. 11, T. 3 N., R. 6 E.	1905	Bored, 10 inches	35	4		Gas	I		40.00	300
John Schiffler	do	1906	Bored, 6 inches	25	4		do	I			200
E. A. Beard	do	1905	Bored, 10 inches	40	6	68	do	I	*a* 25	50.00	250
H. A. Goodman	do			65	5		do	I			*b* 200
C. W. Fish	Sec. 12, T. 3 N., R. 6 E.	1906	Bored, 10 inches	38	6		do	I	*a* 45	60.00	400
Edward Powers	Sec. 10, T. 3 N., R. 6 E.	1904	do	65	8.5		do	I	*a* 65	85.00	610
James Clausen	Sec. 11, T. 3 N., R. 6 E.	1905	Bored	50?	5?		Electric	I			398
H. F. Beckman	do	1904	do	80	4		Gas	I			*b* 800
W. Hieb	Sec. 13, T. 3 N., R. 6 E.		Bored, 6 inches	100	5?		do		*a* 55		450
H. Rinn	do	1904	Bored, 8 inches	62	7		do	I			475
Jacob Koening	do	1904	Bored, 10 inches	54	15		do	I	*a* 70	75.00	600
O. B. Morris	Sec. 18, T. 3 N., R. 7 E.	1905	Bored, 12 inches	75	12?		do	I		50.00	275
P. H. Tindell	Sec. 16, T. 3 N., R. 7 E.	1899	Bored, 8 inches	150	15		do	I	*a* 65		775
Do	Sec. 18, T. 3 N., R. 7 E.	1906	Bored, 12 inches	160	15		Electric	I	*a* 70	225.00	700
J. F. Jungebruit	Sec. 7, T. 3 N., R. 7 E.	1904	Bored, 10 inches	65	14		Gas	I			*b* 700
Julius Woock	do	1906	Bored, 8 inches	36	16		do	I		36.00	500
J. B. Williams	Sec. 8, T. 3 N., R. 7 E.	1905	do	46	16		do	I	*a* 40		*b* 500
F. E. Hosmer	do	1904	Bored, 10 inches	66	17.5		do	I			575
G. A. Grimes	do	1902	Bored, 6 inches	90	17		do	I		55.00	425
O. Pool	do	1905	Bored, 10 inches	110	17		do	I		100.00	575
John Rohrbach	Sec. 17, T. 3 N., R. 7 E.	1906	do	98	17		do	I			*b* 500
Louis Dourin	Sec. 16, T. 3 N., R. 7 E.	1904	do	145	13		do	I	*a* 75		*b* 1,000
John Schmaidt	Sec. 9, T. 3 N., R. 7 E.	1902?	do	90	14.7		do	I	*a* 55	100.00	600
George Mettler	do	1905	do	80	20		do	I		50.00	450
J. Handel	do	1906	do	95	18	66	do	I		68.00	360
Charles Ruess	do	1905	do	75	22		do	I			*b* 600
Fred Hieb	Sec. 15, T. 3 N., R. 7 E.	1905	Bored, 8 inches	50	20		do	I	*a* 55		*b* 550
F. J. Mettler	Sec. 22, T. 3 N., R. 7 E.	1904	Bored, 10 inches	80							
Do	do	1904	do	108	18		Gas	I			*b* 800
John Handel	Sec. 15, T. 3 N., R. 7 E.	1903	do		18		do	I			460
John Hieb	do	1905	do	104	18		do	I	*a* 40		*b* 800
G. Handel	Sec. 21, T. 3 N., R. 7 E.	1906	do	85	15		do	I			650

Fred Schmaidt	do	1906	do	110	13		do	I	[a] 75		[b] 720
L. W. Dye	Sec. 28, T. 3 N., R. 7 E.	1904	do	46	12		do	I		50.00	550
J. F. Loeffler	do	1902	do	95	12		do	I			600
G. J. Loeffler	Sec. 33, T. 3 N., R. 7 E.	1904	do	54							
Do	do	1904	do	14							
Do	do	1904	do	60	12		Gas	I	[a] 55		615
Mrs. Thomas Bunch	Sec. 31, T. 3 N., R. 7 E.	1905	do	136	14		do	I			725
J. C. Dutton	do	1906	do	60	12		do	I			[b] 600
Fred Sanguinetti	Sec. 30, T. 3 N., R. 7 E.	1903?	do	103	8		do	I			400
A. E. Pull	do		Bored, 7 inches	40	9		do	I			
A. S. Laselle	Sec. 25, T. 3 N., R. 6 E.	1904	Bored, 8 inches	90							
Do	do	1904	Bored, 10 inches	90							
Do	do	1904	Bored, 17 inches	218	8		Gas	I	[a] 70	350.00	800
Do	do	1906	Bored, 10 inches	26	4.5		do	I	[a] 20		500
Do	do	1902	do	124	8		do	I			[b] 625
George Weiley	Sec. 30, T. 3 N., R. 7 E.	1906	do	88	10?		do	I			285
George Hogan	Sec. 19, T. 3 N., R. 7 E.	1905	Bored, 12 inches and 8 inches.	55	12		do	I	[a] 95		[b] 1,000
Dr. Haight	do	1903	Bored, 12 inches	65	12		do	I			784
Samuel Ferdun	do	1904	Bored, 12 inches and 3 inches.	115	12		do	I	[a] 125	22.50	
R. E. Ryan [c]	Sec. 24, T. 3 N., R. 6 E.	1904	Bored, 10 inches and 8 inches.	72	13		do	I		100.00	750
David McEvoy	do	1906	Bored, 12 inches	65	11		do	I	[a] 75	60.00	750
Fred Meyers	do	1904	do	50	8		do	I		50.00	750
A. S. Edlemann	do	1904	Bored, 10 inches	85	22		do	I			[b] 500
John Emde	Sec. 15, T. 3 N., R. 6 E.						do	I			
C. L. Boynton	do	1906	Bored	50?	8		do	I			[b] 300
Louis Keshman	Sec. 22, T. 3 N., R. 6 E.	1905?	Bored, 5 inches	37	4		do	D, S			
H. A. Mettler	Sec. 27, T. 3 N., R. 6 E.		Dug	20	8?		Wind	D, S			60
S. H. Eshley	Sec. 34, T. 3 N., R. 6 E.	1901?	Bored, 4 inches	33	4.3		do	D, S			85
E. G. Young	Sec. 4, T. 2 N., R. 6 E.	1901	Bored, 2½ inches	60	12		do	D, S			
George Mosher	Sec. 1, T. 3 N., R. 6 E.	1885?	Bored, 3 inches	75?	9		do	D, S			
Mrs. J. C. Swain	Sec. 12, T. 2 N., R. 6 E.	1891	Bored, 4 inches	180	7		do	D, S			60
W. J. Little	Sec. 10, T. 2 N., R. 6 E.	1888	Bored, 8 inches	1,165?	0	84	Artesian		[a] 9	3,000.00	
G. C. Swain	Sec. 15, T. 2 N., R. 6 E.	1899	Bored, 4 inches	112	8		Wind and gas	D, S			75
J. F. Dolan	Sec. 16, T. 2 N., R. 6 E.	1901	Bored, 3 inches	110	6.3		Wind	D, S		13.00	113
San Joaquin County	do	Old.	Bored, 6 inches	47	6.7		do	R			
J. C. Swain	Sec. 22, T. 2 N., R. 6 E.	1885?	Bored, 4 inches	100?	10.5		do	D, S		30.00	
California State Hospital for Insane	Campo de los Franceses.	1904	do	+100	6.3		do	D, S			125
G. Logorio	do	1904	Bored, 10 inches	128	10?		Gas	I			
Charlotte B. Clowes	do	Old.	Bored, 8 inches	([d])	9?		do	I			260
M. A. Podesto	do	1903?	Bored, 10 inches and 8 inches.	122							
Do	do	1903?	do	137	5?		Gas	I			
Do	do	1903?	Bored, 8 inches	80							
Do	do	1903?	do	165	5?		Ceased flowing	I			
S. Sanguinetti	do	1885	Bored, 8 inches?	1,162	6			N		3,500.00	
San Joaquin County	do	Old.	Bored, 6 inches	38	12.2		Wind	R			

[a] Yield estimated or statement of owner taken.
[b] Cost of well and equipment combined.
[c] Two wells.
[d] Three wells 50–76 feet deep.

TABLE 39.—*Records of wells in San Joaquin, Contra Costa, Calaveras, and Alameda counties*—Continued.

San Joaquin County—Continued.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	*° F.*			*Miner's inches.*		
F. A. West	Campo de los Franceses.		Bored, 10 inches	120	12		Gas	I			
Do	do		do	120	12		Electric	I			
Henry Armbrust [a]	do	1904?	Bored, 8 inches	75	3		Gas	I			[b] $425
Mrs. Zignego	do	1885?	Bored, 7 inches	1,045	0	79	Artesian and gas	I	Small.		
California Traction Co	do	1906	Bored, 8 inches?	117	9		Electric	D			225
G. N. Brown	Stockton	Old.	Bored, $2\frac{1}{2}$ inches	120	10		Wind	D			
Philip Geroni	Campo de los Franceses.	1905	Bored, 8 inches	40	12		Gas	I			225
Louis Risso	do	1907	Bored, 12 inches	55	14		do	I			
D. Smith	do	1905	Bored, 10 inches	150	11		do	I	c 20		
Philip Geroni	do	1906	do	50	8		do	I			
S. Podesto	do	1902	do	60?	8		do	I			
G. Puma Parkarevi	do	1904	Bored, 8 inches	85	15		do	I		$75.00	285
G. Gattorna	do	1906	Bored, 10 inches	79	10		do	I		50.00	285
B. Venaul	do	1905	Bored, 8 inches	80	20		do	I		75.00	275
Mr. Russell [a]	do	1900	Bored, 7 inches	109	7.2		Wind	I			
Bonney & Healey [a]	do		Bored, 10 inches	160	10		Gas	I			
G. Tassano [a]	do	Old.	Bored, 8 inches	50	10		Wind	D, S.			?200
Julia Weber	do	1904	Bored, 7 inches	52	6.8	66	do	D, S.			
W. A. Odor	Sec. 4, T. 2 S., R. 7 E.	1903?	Bored, 12 inches	79	12		Gas	I	c 60		600
Mrs. W. H. Beckman	Sec. 3, T. 2 N., R. 7 E.		Bored, 10 inches	78	11.5		do	I	c 35	100.00	400
James Brumby	do	1906	Bored, 12 inches	200	16		do	I	c 135	230.00	1,000
A. E. Stene	do	1902	Bored, 10 inches	135	13.5		do	I			350
Stephen Soleri	Sec. 9, T. 2 N., R. 7 E.	1905	do	170	12		do	I	c 75	150.00	600
A. McHugh	do	1905	Bored, 12 inches	150?	8		do	I	c 90	100.00	850
Day Bros. [a]	Campo de los Franceses.	1898	Bored, 10 inches	144	14		do	I	c 80	200.00	875
D. Gotelli	do	1906	Bored, 12 inches	170?	18		do	I		150.00	700
S Soleri	do	1906	Bored, 10 inches	150	12		do	I			300
A. Pessi	do		do	100?	9		do	I			600
Henry Hill	do				11.8		do	S, I.			
S. A. Pearson	do	1871?	Bored, 3 inches	85	9		Wind	D, S.			
S. B. Light	Sec. 11, T. 2 N., R. 7 E.	1886	Bored, 7 inches		15		do	D, S.			
B. Sanguinetti	Campo de los Franceses.		Bored, 10 inches	79	5		Gas	I		50.00	400
A. Sanguinetti	do	1902	do	40	12		do	I		50.00	400
N. Arata	do	1906	Bored, 8 inches	135	13?		do	I	c 35	90.00	400

San Joaquin County	do	Old.	Bored, 4 inches	70?	9	68	Wind	R			
Foppiano Bros	Sec. 17, T. 2 N., R. 7 E.	1906	Bored, 10 inches	170	14		Gas	I	c 65	155.00	725
S. Soleri	Campo de los Franceses.	1903	Bored, 12 inches	206	18		do	I			
Do	do	1906	Bored, 10 inches	58	14		do	I			
Day Bros	do	1906	Bored, 6 inches	154	14		do	D, S.	c 9	55.00	225
L. Lagorio	do	1903	Bored, 10 inches	80	9		do	I			
J. Arata [a]	do	1903	Bored, 8 inches	40	12		Wind	I		25.00	200
Do	do	1906	Bored, 10 inches	120	12		Gas	I			400
John Beardot	do	1904	do	100?	12		do	I			450
V. Cella	do	1906	Bored, 8 inches	54	12		do	I			285
G. Borosso	do	1904	Bored, 10 inches	88	14		do	I			
G. Armanino	do	1906	do	135	10		do	I			285
B. Bacicco	do	1906	Bored, 12 inches	70	11		do	I			400
Mrs. T. Donovan	do	1899	Bored, 7 inches	38?	10		Wind	I			
Catherine E. Overhiser	do	1878	Bored, 8 inches	(d)	12		Gas	I			
E. Shioezi	do	1899	Bored, 10 inches	96	5		do	I		45.00	250
Mrs. D. Prato	do	1906	do	90	12		do	I			300
Elizabeth Loeber	do	Old.	Bored, 8 inches	1,128	0	84	Artesian	N	c 2		
San Joaquin County	do	Old.	Bored, 4 inches	30+	10.5		Wind	R			
Do	do	Old.	Bored, 6 inches	40	9.2	67	do	R			
E. S. Beecher	Sec. 25, T. 2 N., R. 7 E.	1903	Bored, 10 inches	100	9		Gas	I		40.00	450
Mr. Alling	Sec. 24, T. 2 N., R. 7 E.	Old.	Bored, 6 inches	27	13.2	69	Wind	D, S.			
L. A. Gremaux	Sec. 7, T. 2 N., R. 8 E.	1901	Bored, 10 inches	110	11.5		Gas	I	c 55	75.00	490
Forest Foote	Sec. 6, T. 2 N., R. 8 E.	1902	Bored, 3 inches	60	17		Wind	D, S.		15.00	60
Smith & Walch	Sec. 5, T. 2 N., R. 8 E.	1891	Bored, 4 inches	50?	18		do	N			
R. L. Holman	Sec. 9, T. 2 N., R. 8 E.	1888	Bored, 7 inches	40	16	68	do	D, S.			50
Mrs. J. P. Ashley	Sec. 15, T. 2 N., R. 8 E.	1878?	Bored, 6 inches	28?	18		do	D, S.			
D. C. Middlekauff	do	1904	Dug, 4 feet	30	20.3	69	Gas	I			280
P. C. Lynch	Sec. 22, T. 2 N., R. 8 E.	Old.	Bored, 7 inches	50	20		Wind	D, S.		45.00	
James Sanguinetti	Sec. 27, T. 2 N., R. 8 E.	1880?	Bored, 4 inches	40	16	67	do	D, S.			
Mrs. Martha Holman	Sec. 28, T. 2 N., R. 8 E.	1866?	Bored, 6 inches	41	12		do	D, S.			
G. H. Grupe	Sec. 30, T. 2 N., R. 8 E.	1903	Bored, 11 inches	70	13		Gas	I	c 40	25.00	425
J. M. Chapin [a]	Sec. 31, T. 2 N., R. 8 E.	1905	Bored, 10 inches	90	10		do	I	c 80		
H. J. Smyth	do	1905	Bored, 7 inches	156	15		do	D, I.	c 6		b 330
F. Montinello	Sec. 5, T. 1 N., R. 8 E.	1905	Bored, 10 inches	150	10		do	I	c 35		
Henry Klinger	Sec. 33, T. 2 N., R. 8 E.	Old.	Bored, 6 inches	20	6.8		Wind	D, S.			
John Perado	do	1907	Bored, 10 inches	161	10		Gas	I			
G. Cavenero	do	1905	Bored, 12 and 6 inches.	80	9?	65	do	I		100.00	400
Louis Carmichen	do	1905	Bored, 12 inches	150	10		do	I		100.00	425
Anton Canagnaro	Sec. 33, T. 1 N., R. 8 E.	1906	Bored, 8 and 6 inches.	115	10		do	I			b 300
Peter Dondero [a]	do	1904?	Bored, 8 inches	80	10	65	do	I	c 20	275.00	
Sidney Newell	Sec. 3, T. 1 N., R. 8 E.	Old.	Bored, 7 inches	85?	10		Wind	S			
R. C. Gruwell	Sec. 35, T. 2 N., R. 8 E.	Old.	Bored, 3½ inches	48	17	66	do	D, S.			
O. Scheffel	do	Old.	Dug, 4 feet	28	16		do	D, S.			
San Joaquin County	Sec. 36, T. 2 N., R. 8 E.	Old.	Bored, 7 inches	90?	24.8		do	R			
Fifield estate	Sec. 25, T. 2 N., R. 8 E.	1866?	Dug, 3 feet	40	27		do	N			
A. D. Fifield	Sec. 24, T. 2 N., R. 8 E.	Old.	Bored, 4 feet	56	42		do	D, S.			

[a] Two wells.
[b] Cost of well and equipment combined.
[c] Yield estimated or statement of owner taken.
[d] Four wells 130-145 feet deep.

TABLE 39.—*Records of wells in San Joaquin, Contra Costa, Calaveras, and Alameda counties*—Continued.

San Joaquin County—Continued.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	° *F.*			*Miner's inches.*		
P. C. Cassell	Sec. 32, T. 2 N., R. 9 E.	1869	Dug and bored	110	74	67	Wind	D, S.			$125
Joe Potter	Sec. 19, T. 2 N., R. 9 E.	1880	Dug, 4 feet	34	28	68	do	D. S.			
Mrs. Wainwright	Sec. 17, T. 2 N., R. 9 E.		Dug and bored	125	108		do	D, S.			
J. F. Helms	Sec. 8, T. 2 N., R. 9 E.	1878	Dug, 4 feet	56	47		do	S.			
Charles Cody	Sec. 5, T. 2 N., R. 9 E.	1880	Dug	40?	32		do	D, S.			
Mrs. D. Lozier	do	Old.	do	80	70		do	D, S.			
Kate D. Winship	Sec. 3, T. 2 N., R. 9 E.	Old.	Dug, 4 by 4 feet	38	27	67	do	S.			
C. P. Coleman	Sec. 2, T. 2 N., R. 9 E.	Old.	do	38	28.5		do	N.			
Morrell Bros.	Sec. 36, T. 3 N., R. 9 E.	Old.	Dug, 3 by 3 feet	46	39	66	do	D, S.			125
C. M. Keeler	Sec. 25, T. 1 N., R. 9 E.	1898	Bored, 3 inches	92	13		do	D, S.			
T. J. Brooke	Sec. 26, T. 1 N., R. 9 E.	1855	Dug and bored	180	13		do	D, S.			
R. Patterson	Sec. 23, T. 1 N., R. 9 E.	1879?	Dug, 3 feet	74	39	65	do	D, S.			
Do.[a]	do	1900	Dug and bored, 10 inches.	140	40		Gas	I.			
Do.	do	1900	do	115	40		do	I.			[b] 1,450
Mrs. Ellen Groves	Sec. 16, T. 1 N., R. 9 E.	1888	Bored, 10 inches	222	30		Wind	D, S.			
M. Delmas	Sec. 4, T. 1 N., R. 9 E.	1865?	Dug, 3 feet	87	77		do	S.			
Kate Winship	Sec. 9, T. 1 N., R. 9 E.	Old.	do	85?	76	70	do	S.			
E. D. Alders	Sec. 17, T. 1 N., R. 9 E.	1876?	Bored, 8 inches	150	40	69	Gas	D, S, I.		$100.00?	575
A. S. Drais	Sec. 18, T. 1 N., R. 9 E.	1901	Bored	160	25		do	D, I.			
W. T. Hewitt	do		Dug and bored		18	69	do	I.			
A. W. Hewitt	Sec. 13, T. 1 N., R. 8 E.	1886	Bored, 7 inches	41	15.2		Wind	D, S.			
San Joaquin County	Sec. 14, T. 1 N., R. 8 E.	1901	do	62	18		do	R.			
Hewlett & Hough	Sec. 15, T. 1 N., R. 8 E.	Old	Bored, 4 inches	20	11.6		do	S.			
Mrs. E. Griffin	Sec. 16, T. 1 N., R. 8 E.	1886?	do	75	12	69	do	D, S.			
T. Minnahen	Sec. 4, T. 1 S., R. 8 E.	1903	do	40?	7		do	S.			
J. Uriell	Sec. 33, T. 1 N., R. 8 E.		Bored	93	8?	70	do	D, S.			
San Joaquin County	Sec. 32, T. 1 N., R. 8 E.	Old.	Bored, 7 inches	34	5.6		do	R.			
W. G. Smith	Sec. 25, T. 1 N., R. 7 E.	1876?	do	98	10		do	S.			
San Joaquin County	Sec. 26, T. 1 N., R. 7 E.	Old.	do	34	4.9		do	R.			
School district	Sec. 7, T. 1 N., R. 8 E.	1902	Bored, 3 inches	84	5.2	70	Hand	D.			
San Joaquin County	Sec. 12, T. 1 N., R. 7 E.	Old.	Bored, 6 inches	46	4.5		Wind	R.			
Dr. Young	Sec. 7, T. 1 N., R. 8 E.	1860	do	11	10		do	S.			
Mrs. S. Bolliger	Sec. 1, T. 1 N., R. 7 E.	1881	Bored, 7 inches	40	10		do	D, S.			
Theo. Kueppers	Campo de los Franceses.		Bored, 10 inches	180			Gas	I.			
Do.	do		do	150	8		do	I.			?900
E. Miller estate	do		Bored, 7 inches	75	10	69	do	S, I.			275

San Joaquin County	Sec. 11, T. 1 N., R. 7 E.	Old.	Bored, 6 inches	70	9		Wind	R			
C. F. Kuhl	Campo de los Franceses.	Old.	Bored, 7 inches	60	11		do	D, S			
Frank Peirano	do	1906	Bored, 12 inches	122	9		Gas	I	c 40	106.00	445
O. Lofquist	do	1906	Bored, 10 inches	62	7		do	I		40.00	
Fred Calosso	do	1904	Bored 8 inches	75?	12		do	I		50.00	250
James Budd	do						do	I			
R. Junker	do	1885?	Bored, 8 inches	1,010	1.5		Ceased flowing				
George Barbero	do	1906	Bored, 10 inches	130	11		Gas	I		100.00	400
Theodore Infelt	do	1905	do	64	11		do	I		48.00	375
P. Repetti	do	1904	do	95	8		do	I		50.00	285
C. L. Box	do	1894	Bored, 4 inches	120	7.5		Wind	D, S			
A. L. Selna	do	1906	Bored, 8 inches	80	12		Gas	I			
Burkett ranch	do	1871?	Bored, 4 inches	30	12		Wind	D, S			
Capetanech Bros	do	1905	Bored, 10 inches	150?	9?		Gas	I	c 30	130.00	450
Marsh estate [a]	do	1900	Bored, 7 inches	100	14		do	I	c 55		
Mrs. S. Y. Strait	do	Old.	do	1,080	0	68	Artesian	I	c 4		
James Rolero [a]	do		do	60?	10	67	do	I			
V. Lagorao	do	1905	Dug and bored	85	12		Gas	I			
Philip Cavellero	do	1906	Bored, 12 inches	175	14		do	I		135.00	490
W. Hollinbeck	do	1900	Bored, 7 inches	60	10		Wind	I			
Do	do	1900	do	100	10	69	do	I			
San Joaquin County	Sec. 27, T. 1 N., R. 7 E.	Old.	do		6		do	R			
Galgiana estate	Campo de los Franceses.	Old.	Bored, 4 inches	55	10?	70	do	S			
San Joaquin County	do	Old.	Bored, 7 inches	40?	2.8		do	R			
George Neilly	do	Old.	Bored, 4 inches	97	9		do	D, S			
W. E. Ladd	do	1880	Bored, 7 inches	975	0	73	Artesian and gas	I	Small.		
B. Sanguinnetti	do	1905	Bored, 8 inches	90	11?		Gas				
George Pock [a]	do	1903	Bored, 10 inches	100	12		do	I	c 65	200.00	700
G. B. Sanguinnetti & Co	do	1906	do	70	15		do	I			283
G. Boscacci	Stockton	Old.	Bored, 3½ inches	30	10.8	68	Hand	D			
Mr. Smith	do		Bored, 3 inches	85	10.5		Wind	D			
S. Bragetta	do	1890?	Bored, 8 inches	45	12.5		do	D, I			
Stockton Water Co.	do		(d)	(d)	12		Steam	D	c 225		
Julia Gaedke	do	1890	Bored, 7 inches	100	9		Wind	D			
Stockton Gas & Electric Co	do	1893	Bored, 12 inches	1,800	0	97	Artesian	N	c 5		
State Hospital for Insane	do	1894	Bored, 15 to 8 inches.	1,990	0	91	do	N			
Do	do	Old.	Bored, 8 inches ?	1,000?	10		Gas	I			
Do	do	1900?	Bored, 8 inches	80			Steam	D			
Do	do	1900?	do	150	10		do	D			
G. Scopesi	Campo de los Franceses.	1906	do	125	12		Gas	I		42.00	275
State Hospital for Insane	Stockton	1892	Bored	1,750	0	88	Artesian	N	c 10		
Stockton Gas & Electric Co	do	1895	Bored, 12 to 9 inches.	1,498	0	89	do	N	c 15		
Citizens Gas Co	do	1890	Bored, 12 inches ?	2,078	0	96	do	N	c 125		
Stockton Water Co. [a]	do	1903–4	Bored, 12 inches	800	10		Electric	D	c 185		

[a] Two wells.
[b] Cost of well and equipment combined.
[c] Yield estimated or statement of owner taken.
[d] Eleven wells, 8–20 inches in diameter and 200–1,100 feet deep.

TABLE 39.—*Records of wells in San Joaquin, Contra Costa, Calaveras, and Alameda counties*—Continued.

San Joaquin County—Continued.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	° *F.*			*Miner's inches.*		
Central Natural Gas Co.	Stockton			1,400	0		Artesian	N			
Citizens Gas Co.	do	1904	Bored	1,786	0	94	do	N	*a* 125		
Crown Mills	do	1890	do	1,210	0	90	do	N	*a* 10		
Stockton Gas & Electric Co.	do	1899	Bored, 12 inches	2,500	0	101	do	N			
California Paper Co.	do		Bored, 12 to 6 inches.	1,228	0		do	N		$2,500.00	
Stockton Gas & Electric Co.	do	1888	Bored	2,254			Ceased flowing	N			
Do	do	1890	do	1,400	0		Artesian	N	Small.		
Do	do	1892?	Bored, 12 to 7 inches.	1,800	0		do	N			
Citizens Gas Co.	do	1890	Bored, 12 to 6 inches.	2,078	0		do	N			
Do	do	1903	do	1,600?	0		do	N			
San Joaquin County	do	1890	Bored, 12 to 8 inches.	2,000	3		Ceased flowing	N		5,584.00	
San Joaquin County and Stockton	do	1857	Bored, 9 to 8 inches.	1,003	0	77	Artesian	N		10,000.00	
St. Agnew's College	do	1889	Bored		0		do				
Do	do	1892	Bored, 10 to 6 inches.	1,720	0		do		*a* 10		
George Dawson	do	1898	Bored, 4 inches	110	3?		Wind	D			
Dr. Clark	do		Bored, 10 inches	90	5?		Gas	I			
Suren Jackson	do	1893-4	Bored, 12 to 9 inches.	1,700	0	85	Artesian	Baths.	} *a* 50		
Do	do	1893-4	do	1,850	0	85	do	Baths.			
Pacific Window Glass Co.	do		Bored, 12 inches	2,100?	0	88	do		*a* 15		
W. S. Moss estate	Campo de los Franceses.	Old.	Bored, 4 inches	40	5.5		Wind	D, S			
H. P. Fitch	do	1901?	Bored, 9½ inches	200?	4		Gas	I		100.00?	$275
Mr. Zinango	do	1885?	Bored, 7 inches	60							
Do	do		do	35	15	66	Wind	I			
Mrs. C. Fraser	do	Old.	Bored, 6 inches	60	10		do	D, S			40
A. C. Ashley	do	Old.	Bored, 4 inches	70	20		do	D, S			
A. Baker	do	Old.	Bored, 8 inches	80	25		do	S, I			125
Michael Earney	Sec. 28, T. 1 N., R. 7 E.	1892	Bored, 4 inches	80	8		do	D, S			
Mrs. Keller	Sec. 27, T. 1 N., R. 7 E.	1882	do	100	20		do	D			
Dr. Asa Clark *b*	Campo de los Franceses.		Bored, 18 to 15 inches.	106	4.5		Gas	I			
Sperry Flour Co.	do	Old.	Bored, 4 inches		10	67	Wind	D, S			

C. B. McDougald	Sec. 26, T. 1 N., R. 6 E.	Old.	Bored				Ceased flowing	N			
San Joaquin County	Sec. 16, T. 1 N., R. 6 E.	Old.	Bored, 7 inches	23	3		Wind	R			
J. J. Sober	do	1898	Bored, 4 inches	100	4.5		do	D, S.			
Do.	Sec. 19, T. 1 N., R. 6 E.		Bored, 6 inches	23	6.7	62	do	S.			
School district	Sec. 7, T. 1 N., R. 6 E.	Old.	Bored, 3½ inches	33	4.3		Hand	D			
Charles D. Puerst Land & Sales Co.	Sec. 6, T. 1 N., R. 6 E.	1907	Bored, 7 inches	90	2.5		Wind	D			
Wood Bros	Sec. 24, T. 1 N., R. 5 E.		Bored, 4 inches	40	5?		do	D, S.			
W. J. Thompson	Sec. 23, T. 1 N., R. 5 E.		do	38	11	65	do	D, I.			
San Joaquin County	Sec. 20, T. 1 N., R. 6 E.	Old.	Bored, 7 inches	85	4.5		Not raised	N			
A. Grunaur	Sec. 29, T. 1 N., R. 6 E.	Old.	Bored, 3 inches		10.5	64	Wind	D, S.			
J. J. Cassiday	Sec. 32, T. 1 N., R. 6 E.		do	32	11		do	D, S.			
L. J. Squires	Campo de los Franceses.	1903?	Bored, 8 inches	110	11		Gas	I		100.00?	400
S. A. Gaffney	do	1903	Bored, 12 inches	182	13		do	I	a 50		c 500
J. P. Wilson	do	1904	Bored, 8 inches	110	14		Gas	I			
Joseph Yettner b	do	1904	Bored, 8 inches?	200	8		do	I			c 1,500
Lorenzo Hurd	do	1905	Bored, 12 inches	213	14		do	I		300.00	335
William Brown	Sec. 6, T. 1 S., R. 6 E.	1890	Bored, 7 inches	30	11	66	Hand	D, S.			
J. Woods	Sec. 1, T. 1 S., R. 5 E.	Old.	Bored, 2½ inches	52	5.5	65	do	D, S.			
J. Williams	Sec. 2, T. 1 S., R. 5 E.	Old.	Bored, 7 inches		10.5		Wind	D, S.			
Frank H. Johnson	Sec. 22, T. 1 S., R. 5 E.	1884	Bored, 10 inches	1,400	0	84	Artesian	N			
Do.	do		Bored, 7 inches	30	8	65	Wind	D, S.			
Henry Meyers	Sec. 19, T. 1 S., R. 6 E.	1898?	Bored, 3 inches	80	8	66	do	D, S.			
J. F. Kranz	Sec. 20, T. 1 S., R. 6 E.	1897	Bored, 4 inches	43	9		do	D, S.			
Do.	Sec. 17, T. 1 S., R. 6 E.	1897	Bored, 3 inches	40	9		do	D, S.			
G. F. Slankard	Campo de los Franceses.	1904	Bored, 8 inches	130	8		Gas	D, S.			600
Nicola Grecco	do	1906	Bored, 6 inches	108	9		Gas	I	a 20	54.00	280
W. J. Rhoades	do	1905	Bored, 11 inches	123	9	67	do	I, S.		123.00	450
Do.	do	1905	Bored, 16 inches	107	9		do	I, S.	a 211	300.00	2,150
J. A. McAfee	do	1898	Bored, 2½ inches	200	11		Wind	D, S.			
Burdett Salmon	do	Old.	Bored	1,200	0		Artesian	N	a 5		
Mrs. Nellie Comstock	Sec. 8, T. 1 S., R. 7 E.	1881?	Bored, 7 inches	1,250	0	77	do	N			
H. A. Hoerl	Sec. 13, T. 1 S., R. 6 E.	1906	Bored, 12 inches	90	10		Gas	I	100	128.00	700
Mrs. Anna Ross	Sec. 24, T. 1 S., R. 6 E.	1906	do	125	7		do	I	133	150.00	900
T. M. Brockman	Sec. 25, T. 1 S., R. 6 E.	1906	do	115	9		do	I	100	20.00	650
P. Alex	Sec. 26, T. 1 S., R. 6 E.	1903	Bored, 10 inches	44	9	59	do	I	25	80.00	450
W. Litchfield	do	1906	Bored, 12 inches	131	10	58	Gas	I	100	200.00	
L. W. Holland	do	1905	Bored, 10 inches	50	16	62	do	I	45		675
	Sec. 25, T. 1 S., R. 6 E.	1890	Bored, 8 inches	1,200	0	74	Artesian	N	8		
Mrs. Garrison	Sec. 36, T. 1 S., R. 6 E.	Old.	Bored, 7 inches	48	10?	58	Wind	D, S.			
G. H. Shedd	do	1896	Bored, 2 inches	80	8		do	D, S.		15.00	60
A. E. Munter	Sec. 1, T. 2 S., R. 6 E.	1891	Bored, 4 inches	100	18		do	D, S.			
E. R. Olds	Sec. 32, T. 1 S., R. 7 E.	1905	do	70	12		do	D, S.			80
D. R. Reynolds	Sec. 30, T. 1 S., R. 7 E.	1871	do	35	7	65	do	D, S.			40
Mrs. E. F. Salmon	Sec. 29, T. 1 S., R. 7 E.	Old.	Bored, 5 inches	75	15		do	D, S.			
E. Reynolds	Sec. 30, T. 1 S., R. 7 E.	1905	Bored, 16 inches	115	14	64	Gas	I	a 177	250.00	1,000
D. O. Castle	Sec. 16, T. 1 S., R. 7 E.	1898	Bored, 3 inches	40	5		Wind	D, S.			
M. Henry	Sec. 15, T. 1 S., R. 7 E.	1899	Bored, 6 inches	130	5.8		do	D, S.			
Josephine Hitchcock	Sec. 23, T. 1 S., R. 7 E.	1885?	do	28	3.5	66	do	D, S.			
C. A. Miller	Sec. 24, T. 1 S., R. 7 E.	1883	Bored, 4 inches	45	3.5		do	D, S.			

a Yield estimated or statement of owner taken. b Two wells. c Cost of well and equipment combined.

TABLE 39.—*Records of wells in San Joaquin, Contra Costa, Calaveras, and Alameda counties*—Continued.

San Joaquin County—Continued.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	° *F.*			*Miner's inches.*		
M. N. Foster	Sec. 30, T. 1 S., R. 8 E.	1903	Bored, 4 inches	120	4		Wind	D, S.			
Albert Due	Sec. 20, T. 1 S., R. 8 E.	1885?	do	100?	11	64	do	D, S.			
J. Demichelis [a]	Sec. 21, T. 1 S., R. 8 E.	1901	Bored, 10 inches	30	3		Gas	I.			$800
G. S. Hall	Sec. 16, T. 1 S., R. 8 E.	1890	Bored, 7 inches	50	5.5		Wind	I.			
G. W. Mourey	Sec. 3, T. 1 S., R. 8 E.		Dug	18	10		do	I.			
B. F. Hardin	Sec. 15, T. 1 S., R. 8 E.	1886?	Bored, 4 inches	67	4.7		do	I.			
Minges estate	Sec. 23, T. 1 S., R. 8 E.	1886?	Bored, 3 inches	50?	16		do	I.			
Louis Cook	Sec. 28, T. 1 S., R. 8 E.	1886?	Bored	60	8	66	do	I.			
Due estate	Sec. 32, T. 1 S., R. 8 E.	1890?	Bored, 4 inches	29	8		Hand	N.			
James Turner	do	1891?	Bored, 10 inches	21	10.8		Wind	D, S.			
G. E. Mindes	Sec. 33, T. 1 S., R. 8 E.	1888	Bored, 4 inches	31	11.3	67	do	D, S.			
E. Wagner	Sec. 4, T. 2 S., R. 8 E.	1869	Bored, 6 inches	24	13.7		do	D, S.			
G. H. Liesy	Sec. 3, T. 2 S., R. 8 E.	1876?	do	70?	20		do	D, S.			
School district	Sec. 6, T. 1 S., R. 8 E.		Bored, 7 inches	40+	22.5		do	D.			
Fred Holmsten	Sec. 31, T. 1 S., R. 9 E.	1886?	Bored	48	28		do	D, S.			
Charles Sutherland	Sec. 19, T. 1 S., R. 9 E.	1876?	do	60	2		do	D, S.			
Hiram Jones estate	Sec. 29, T. 1 S., R. 9 E.	1886	Bored, 7 inches	90	37.5		do	D, S.			
J. H. Strother	Sec. 9, T. 1 S., R. 9 E.	1885?	do	65	40		do	D, S.			
S. C. Fisher	Sec. 5, T. 1 S., R. 9 E.	1907	do	63	21.5		Not installed				
Santa Fe Ry. Co.	Sec. 4, T. 2 S., R. 9 E.	1896?	do	200?	32	69	Steam	B.	*b* $9		
William Campbell	Sec. 3, T. 2 S., R. 9 E.	1895?	do	80	43		Wind	D, S.			
Jones estate	Sec. 1, T. 2 S., R. 9 E.	1885?	Bored, 7 inches	94	63		do	D, S.			
Mrs. D. Sutliff	Sec. 12, T. 2 S., R. 9 E.	1891	do	102	60	68	do	D, S.			
D. L. Jones	Sec. 16, T. 2 S., R. 9 E.	1890	do	100	51		do	D, S.			200
Myers Bros	Sec. 17, T. 2 S., R. 9 E.	1876?	Dug, 3 feet	50	32.5		do	D, S.			
John Hall	Sec. 19, T. 2 S., R. 9 E.	1886?	Bored, 7 inches	70	26	68	do	D, S.			
Mrs. Tottrell	Sec. 24, T. 2 S., R. 8 E.	1871	do	40	29?		do	D, S.			50
Mrs. Eichoff	Sec. 14, T. 2 S., R. 8 E.	1875?	do	75	24.9		do	D, S.			
J. S. Moulton	Sec. 20, T. 2 S., R. 8 E.	1907	Bored, 14 inches	128	22		Gas	I.		250.00	668
G. B. Matthews	do	1906	Bored, 7 inches	42	11		Wind	D, S.		21.00	40
Dan O'Leary [a]	Sec. 17, T. 2 S., R. 8 E.	1905	Bored, 10 inches	130	14		Gas	I.			
J. B. Thorpe	Sec. 7, T. 2 S., R. 8 E.	1901	Bored, 7 inches	65	20		do	I.			*c* 600
G. W. Samson	Sec. 35, T. 2 S., R. 7 E.	1886?	Bored	20	16	61	Wind	D, S.			
Mrs. Frank Hutchinson	do	1891?	Bored, 7 inches	35	13		do	D, S.		22.00	90
Joe Willard	Sec. 27, T. 2 S., R. 7 E.	1905	Bored	80			do	D.			
W. J. Buchanan	Sec. 15, T. 2 S., R. 7 E.	1905	Bored, 6 inches	40	11		do	D, S.		25.00	40
John Swett	do		Bored				Gas	I.			
William Mozer	Sec. 14, T. 2 S., R. 7 E.	1904	do	85	14		Wind	D, S.			

Hals Bros	Sec. 11, T. 2 S., R. 7 E.	1905	Bored, 4 inches	34	9		Hand	D		16.00	
Mrs. B. McMullin	Sec. 20, T. 2 S., R. 7 E.	Old.	Bored	45	30?	62	Wind	S.			
J. W. Thompson estate	Sec. 13, T. 2 S., R. 6 E.	1899	Bored, 10 inches	131	16	59	Gas	I.	95		
West & Wilhoyt	Sec. 8, T. 2 S., R. 7 E.	1900	Bored, 4 inches	100	10		Wind	D, S.			
W. J. Woodward	Sec. 7, T. 2 S., R. 7 E.	1905	Bored, 12 inches	102	13	66	Gas	I.	b 110	170.00	2,000
H. B. Bright	Sec. 2, T. 2 S., R. 6 E.	1898	Bored, 10 inches	125	6	62	do	I.		125.00	860
Mr. Varney	Sec. 12, T. 2 S., R. 6 E.		Bored, 4 inches	36	16	62	Wind	D, S.			
G. W. Wetherby	Sec. 11, T. 2 S., R. 6 E.	1904	Bored	80	8	62	do	D, S.			
W. M. Robinson	Sec. 24, T. 2 S., R. 5 E.	1899	Dug, 3 feet	20	12.7		Wind and gas	D, I.			
McLaughlin & Co	El Pescadero (Grimes).		Bored	29	5		Wind	D, S.			
Do	do	1890	Dug, 3 feet	12	9	72	do	D, S.			
Mrs. M. R. Robbins	do	1899	Bored, 6 inches	80	4.5		do	D, S.			
Mournian Bros	Sec. 32, T. 2 S., R. 4 E.	1888	Dug, 4 feet	37	32		do	D, S.			60
Mrs. E. Hewson	Sec. 4, T. 2 S., R. 4 E.	1886?	Dug, 3 feet	50	45		do	D, S.			120
William Liendemann	Sec. 8, T. 2 S., R. 4 E.	1880	Bored	100	90		do	D, S.			26
McLaughlin & Co	Sec. 9, T. 2 S., R. 4 E.	Old.	Bored, 8 inches	65	40		do	D, S.			
Fabian & Co	Sec. 10, T. 2 S., R. 4 E.	Old.	Bored, 7 inches	95	38		do	D, S.			
P. Hansen	do	1866?	Dug, 3 feet	40	33.6		do	S.			
D. J. Tooney	Sec. 11, T. 2 S., R. 4 E.	1899	Bored, 6 inches	75	30		do	D, S.		107.00	
Mrs. Emily Odell	Sec. 17, T. 2 S., R. 4 E.	Old.	Bored, 7 inches	125	85		do	D, S.			
George Luhrsen	Sec. 14, T. 2 S., R. 4 E.		Bored, 8 inches	167	45		do	D, S.			
Pacific Coast Oil Co	Sec. 13, T. 2 S., R. 4 E.	1904	do	468	12		Steam	D, B.			
Mrs. Coogan	Sec. 22, T. 2 S., R. 4 E.	1871?	Bored, 7 inches	200			Wind	D			
T. H. Henderson	do	1888	do	160	94		do	D, S.			
J. E. Faulkner	Sec. 21, T. 2 S., R. 4 E.	1900	do	200	112		do	D, S.			210
H. Boltzen	Sec. 28, T. 2 S., R. 4 E.	1885	Bored	455	80		do	D, S.			
Hall Cordez	Sec. 27, T. 2 S., R. 4 E.	Old.	Bored, 7 inches	300	180		do	D, S.			
J. A. Cordes	Sec. 34, T. 2 S., R. 4 E.		Bored, 6 inches	+93	93+		do	D, S.			
Fabian & Co	Sec. 33, T. 2 S., R. 4 E.	1897?	Bored, 7 inches	200	.7	72	Hand	D, S.		350.00	
Mrs. S. Slickman	Sec. 34, T. 2 S., R. 4 E.		Dug, 3 feet	30	27	63	do	D, S.			
A. Frahmann	Sec. 35, T. 2 S., R. 4 E.	1868	Bored, 8 inches	200	160		Wind	D, S.			c 225
Fabian & Co	Sec. 25, T. 2 S., R. 4 E.		Dug, 3 feet	97	88.8		do	N.			
Do	Sec. 30, T. 2 S., R. 5 E.	1889?	Bored, 8 inches	50	28		do	D, S.			35
Peter Holm	Sec. 24, T. 2 S., R. 4 E.		Dug, 3 feet	38	34.5	67	do	D, S.			
F. Von Sosten	do	1897	Bored, 8 inches	247	30		do	D, S.		300.00	75
John G. Deane	Sec. 20, T. 2 S., R. 5 E.	1895?		72	15	69	do	D, S.		50.00	27
William Golden	do		Dug, 3 feet	27	24.5		do	D, S.			
J. S. Krohn	Sec. 30, T. 2 S., R. 5 E.	1885	Bored	100	28		do	D, S.			
Southern Pacific Co	Sec. 28, T. 2 S., R. 5 E.	1898	Bored, 10 inches	157	30		Gas	B	b 13		
A. Grunauer	Sec. 22, T. 2 S., R. 5 E.	1906	Bored, 8 inches	698	29	67				2,600.00	
John Chrisman	do	1867	Dug and bored, 7 inches.	45	31		Wind	D, S.		80.00	
C. M. Batterman	Sec. 24, T. 2 S., R. 5 E.	1898	Dug	+37	30.5	69	Hand	D, S.			
Jacob Rhodes	Sec. 30, T. 2 S., R. 6 E.	1869	Bored	52	30		Wind	D, S.		62.00	140
J. Rathaen	Sec. 36, T. 2 S., R. 5 E.	1867	Bored, 6 inches	110	40		do	D, S.			160
H. R. Ludwig	Sec. 2, T. 3 S., R. 5 E.	Old.	Bored, 7 inches	175	80		do	D, S.			
A. Buschke	Sec. 33, T. 2 S., R. 5 E.	1888	Bored	140	100		do	D, S.			
Tracy cemetery	Sec. 28, T. 2 S., R. 5 E.		Bored, 7 inches	76	57		do	I.			
John Frerichs	Sec. 32, T. 2 S., R. 5 E.	1886?	do	130	80		do	D, S.			
William Carroll	Sec. 4, T. 2 S., R. 5 E.	1888	Bored	90	40		do	D, S.			
Fabian & Grunaur	Sec. 7, T. 3 S., R. 5 E.		Bored, 8 inches?	130			do	D, S.			

a Two wells. b Yield estimated or statement of owner taken. c Cost of well and equipment combined.

TABLE 39.—*Records of wells in San Joaquin, Contra Costa, Calaveras, and Alameda counties*—Continued.

San Joaquin County—Continued.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	*° F.*			*Miner's inches.*		
John Collins	Sec. 8, T. 5 S., R. 5 E.	1882	Bored, 7 inches	154	148		Wind	D, S			
School district	Sec. 8, T. 3 S., R. 5 E.	1899	do	200	170		do	D, S			
Mrs. S. M. Schlossman	Sec. 10, T. 3 S., R. 5 E.	1882	Bored, 8 inches	135	120		do	D, S			$200
J. Brichgetto	do	Old.	Bored, 7 inches	125	96.8		do	D, S			
Ed. Mitchell	Sec. 2, T. 3 S., R. 5 E.	Old.	do	89	68		do	D, S			
John Rogers	Sec. 6, T. 3 S., R. 6 E.		Bored, 8 inches	70	43		do	D, S			
J. W. Peterman	do	1903	Bored, 6 inches	132	33		do	D, S		$100.00	
Bert Ebe	Sec. 8, T. 3 S., R. 6 E.		Bored, 7 inches		36		do	D, S			
	Sec. 7, T. 3 S., R. 6 E.		do	150	51.9		do	D, S			
Mrs. M. Schroeder	Sec. 13, T. 3 S., R. 5 E.	Old.	do	72	66		do	D, S			
D. Gerlash	Sec. 23, T. 3 S., R. 5 E.	1895	do	150	95		do	D, S		225.00	125
C. Brandeman	Sec. 10, T. 3 S., R. 5 E.	1866?	do	147	120		do	D, S			
Benjamin Worcester	Sec. 16, T. 3 S., R. 5 E.		do	200	110		do	D, S			
N. Conelly	Sec. 21, T. 3 S., R. 5 E.		Bored, 8 inches	176	165		do	D, S		175.00	220
J. Brichgetto	Sec. 27, T. 3 S., R. 5 E.	1905	Bored, 10 inches	272	212		do	N			
E. Kern	Sec. 22, T. 3 S., R. 5 E.	1903	Bored, 7 inches	173	115		do	D, S			
J. Brichgetto	Sec. 26, T. 3 S., R. 5 E.	1881?	do	180	175		do	D, S			
Jacob Ohm	El Pescadero (Grimes).	1866?	Bored, 6 inches	50	45		do	S			
T. Nicholson	Sec. 30, T. 3 S., R. 6 E.		Bored, 8 inches	150	140		do	D, S			200
School district	Sec. 16, T. 3 S., R. 6 E.		Bored, 6 inches	124	54		do				
Stockton Savings & Loan Association	Sec. 17, T. 3 S., R. 6 E.	Old.	Bored, 7 inches	110	32+		do	D, S			
Stockton Savings Bank	El Pescadero (Grimes).		do		15		do	D, S			
L. Gerlach	do	1886	Bored	80	12		do	D, S			
Do	do		Bored, 6 inches	180	19.1		do	D, S			
John Ohm	do	1886?	Bored, 7 inches	120	20		do	D, S		100.00	100
Jacob Ohm	Sec. 35, T. 3 S., R. 6 E.	1896	do	112	60		do	D, S		130.00	50
Richard Brown	Sec. 4, T. 4 S., R. 6 E.	1896	Bored, 8 inches	175	110		do	D, S		300.00	250
George Thoming	Sec. 32, T. 3 S., R. 6 E.	1886	Bored	140	135		do	D, S			
N. Koster	do	1893	Bored, 7 inches	190	168		do	D, S		205.00	265
J. Brichgetto	Sec. 6, T. 4 S., R. 6 E.	1893	Bored	232	220		do	D, S			
D. K. Fake	Sec. 36, T. 3 S., R. 5 E.	1891	Bored, 8 inches	264	180		do	D, S			

Contra Costa County.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
Mr. Hooper	Los Medanos	1892	Bored	30	22.3		Wind	D, S			
Do	do	Old.	Bored, 6 inches	80	55		do	D, S			

Pacific Coast Oil Co	do	1904	Bored, 8 inches	166	70		Steam	D, B			
C. A. Hooper	do	1881?	Bored, 6 inches	65	15		Wind	D, S			
Mr. Williamson	do	1891	Dug	100	90		do	D, S			
Do	do		Bored, 7 inches		22.7		do	D, S			
Thomas Wallace	do	1892?	Bored	60	40		do	D			
J. H. Trythall	Sec. 19, T. 2 N., R. 2 E.	1896	do	35	29		do	D			50
Mrs. M. E. Evans	Sec. 20, T. 2 N., R. 2 E.	1902	do	65	30		do	D, S		80.00	
	Sec. 21, T. 2 N., R. 2 E.		Bored, 8 inches	61	33.2		do	D			
S. T. Heimbach	Sec. 22, T. 2 N., R. 2 E.	1902	Bored	82	60	62	do	D			70
J. Rodriguez	do	1894	Bored, 6 inches	65	45		do	D			
Mrs. Schultz	Sec. 26, T. 2 N., R. 2 E.	1891	Bored, 7 inches		55		do	D			
R. P. Banenti	Sec. 25, T. 2 N., R. 2 E.	1904	do	70	22.6		do	D		52.00	
B. F. Porter estate	do	1886	Bored	65	10		do	D, S			
F. Enas	Sec. 30, T. 2 N., R. 3 E.	Old.	Bored, 6 inches	28	24		do	D, S			
Mrs. F. M. Morton	Sec. 31, T. 2 N., R. 3 E.		Bored, 10 inches	72	14		Gas	I			
George Sellers	do	1902	Bored, 8 inches	36	13		do	I	a 40	36.00	390
O. C. Austen	do	1902	do	31	11		do	I	20		b 392
Mrs. L. Barnum	Sec. 36, T. 2 N., R. 2 E.	1891	Driven, 7 inches	54	36		do	D			70
A. Whitaker	Sec. 35, T. 2 N., R. 2 E.	1906	Dug, 4 feet	65	62.5		Hand	D			
McLaughlin Co	Sec. 1, T. 1 N., R. 2 E.		Bored	75			Wind	D, S			
Robert Cakebread	Sec. 2, T. 1 N., R. 2 E.		do	600	60		do	S			
Frank McFarland	Sec. 3, T. 1 N., R. 2 E.	1890	Dug, 4 feet	75	5.5		do	D, S			
W. C. Williamson	Sec. 4, T. 1 N., R. 2 E.	1881?	Dug	36	16		do	S			45
	Los Medanos		Dug, 3 feet		40.5		do	D, S			
Los Medanos	do	1902	Bored, 6 inches	72	40	66	do	D, S			
Marsh Grant	do	Old.	do	61	32.5		do	D, S			
Gedes & Rindigen	do	1886?	Bored, 8 inches	140	40		do	D, S			
R. E. Le Moin	Sec. 7, T. 1 N., R. 3 E.	Old.	Bored, 6 inches	100	50		do	D, S		100.00	
J. R. Bayer	Sec. 8, T. 1 N., R. 3 E.	1900	do	50			do	D			
W. F. Pierce	Sec. 4, T. 1 N., R. 3 E.	1891	Bored, 7 inches	60	15		do	D		50.00	50
George Alfritz & Co	Sec. 3, T. 1 N., R. 3 E.	Old.	Dug, 3 feet	35	15		do	D, S			45
W. J. Estes	Sec. 10, T. 1 N., R. 3 E.	1866	Bored, 6 inches	30	16		do	D, S			
D. Rhodes	Sec. 14, T. 1 N., R. 3 E.	1876	Dug, 3 feet	14	10	68	Hand	D, S			
E. D. Griggsby	Sec. 16, T. 1 N., R. 3 E.	1876?	Bored	80	18		Wind	D, S			
Do	Sec. 17, T. 1 N., R. 3 E.	1886?	Bored, 6 inches	75	35		do	D, S			80
P. G. King	Sec. 20, T. 1 N., R. 3 E.	Old.	do		26		do	D, S			
Marsh Grant	Los Medanos	Old.	do	50			do	D, S			
Mellow & Doulart	do	Old.	Dug	27	23	64	Hand	D			
John Boyd	do	1898	do	77	73		do	D, S		14.00	40
Pacific Coast Oil Co	Sec. 29, T. 1 N., R. 3 E.	1904	Bored, 8 inches	367	4?		Steam	D, B			
A. Allen	Sec. 28, T. 1 N., R. 3 E.	1904	Bored, 5 inches	48	29		Wind	D, S		22.00	
P. Buedewick	Sec. 27, T. 1 N., R. 3 E.	1891	Bored, 8 inches	60	30		do	D, S			
M. A. Michaelson	do	1887	Bored, 6 inches	52	12		do	S, I			
J. Q. Wrenn	Sec. 26, T. 1 N., R. 3 E.	Old.	Bored, 10 inches	300	7		do	S, I			
C. W. Lent	Sec. 23, T. 1 N., R. 3 E.		Bored, 6 inches	195	10		Not raised	N			
W. J. Livingston	Sec. 34, T. 1 N., R. 3 E.	Old.	Bored	+100	15		Wind	D, S			
J. S. Netherton	Sec. 28, T. 1 N., R. 3 E.	1876?	Bored, 3 inches	32	16	64	Hand	D			
V. Taylor	Sec. 33, T. 1 N., R. 3 E.	1874	Bored, 5 inches	40	23		Wind	D		40.00	100
A. M. Plumley	Sec. 34, T. 1 N., R. 3 E.	1899?			8		do	D			
W. M. Chilson	Sec. 3, T. 1 S., R. 3 E.	1904	Bored, 7 inches	48	14	61	Gas	I			130
W. A. Farthingham	Sec. 2, T. 1 S., R. 3 E.	Old.	Bored, 6 inches		6		Wind	D, S			

a Yield estimated or statement of owner taken.

b Cost of well and equipment combined.

TABLE 39.—*Records of wells in San Joaquin, Contra Costa, Calaveras, and Alameda counties*—Continued.

Contra Costa County—Continued.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	° *F.*			*Miner's inches.*		
N. Peterman	Sec. 11, T. 1 S., R. 3 E.	1905	Bored, 12 inches	45	7	61	Gas	I.	*a* 110	$90.00	$600
W. W. Stone	Sec. 10, T. 1 S., R. 3 E.	1895	Bored, 6 inches	21	13	62	Wind	D, S.		12.00	104
B. Nelson	do	1886?	Bored	60			do	D, S.			
Mrs. M. Schmidt	Sec. 4, T. 1 S., R. 3 E.	1871?	Bored, 7 inches	46	17		do	D, S.			
E. M. Anderson	Sec. 22, T. 1 S., R. 3 E.		Dug, 4 feet		14.5	62	do	D, S.			
Mrs. M. Klesow	do		Dug, 3 feet	45	37	70	Hand	D.			
H. Bruns	Sec. 26, T. 1 S., R. 3 E.		Dug	30			Wind	D.			
C. F. Wright	do	1889	Dug, 3 feet	42	30	69	do	D, S.			130
Fabian & Co.	Sec. 30, T. 1 S., R. 4 E.		do		30		Hand	D.			

Calaveras County.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
R. L. Peterson	Sec. 14, T. 2 N., R. 10 E.	1890	Bored, 6 inches	315	160		Wind	D.			
Rhodes & Co.	Sec. 10, T. 2 N., R. 10 E.	1901	Bored, 13 inches	850?	160		Not raised	N.			
E. F. Gall	Sec. 9, T. 2 N., R. 10 E.	1890	Dug, 4 feet	110	99		Wind	D, S.			$100

Alameda County.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
James Faulkner	Sec. 20, T. 2 S., R. 4 E.		Bored, 4 inches	200	0	69	Artesian	S.	Small.		
H. C. Peterson	Sec. 6, T. 2 S., R. 4 E.	1902	Dug, 4 feet	74	62		Wind	S.			$40
A. D. Gordon	Sec. 36, T. 1 S., R. 4 E.	Old.	Dug				do	S.			

a Yield estimated or statement of owner taken.

STANISLAUS COUNTY.

GENERAL CONDITIONS.

Stanislaus County, like Merced, extends entirely across San Joaquin Valley, and therefore both east-side and west-side conditions are represented within it. The valley in this latitude is contracted somewhat, so that its width is greater both to the north and to the south than here.

South of Tuolumne River and east of the San Joaquin, the canals of the Turlock irrigation district supply gravity water to a large part of the valley; and north of the Tuolumne the canals of the Modesto district supply the west-central part of the county from a point about 8 miles east of Modesto to San Joaquin River. West of the San Joaquin the lower line of the San Joaquin and Kings River canal system extends to the vicinity of Crows Landing. Under these canal systems much alfalfa is raised, dairying is an important and growing industry, and there is an increasing acreage devoted to fruit raising and diversified farming. Outside of the irrigated district the greater part of the valley lands are in grain, both wheat and barley being raised, although here, as in other parts of the Great Valley, the production is less than formerly. Along the San Joaquin the flooded bottoms and the neighboring alkali lands are used for grazing.

Less use is made of ground waters in this county than in any other part of the valley. The rainfall is sufficient, so that grain raising has been successful in the past, and irrigation has not been absolutely necessary in order that the valley lands might be utilized. The pressure for irrigation therefore has not been so intense as in the more strictly arid sections farther south. Furthermore, the surface supply is more nearly adequate than in many of the counties, and the limits of productivity through the use of the cheap gravity waters have not been reached, because the Turlock and Modesto districts are not yet fully developed. Because of this large supply of surface water and its as yet incomplete utilization little interest has been taken heretofore in the development and use of ground waters.

FLOWING WELLS.

The Survey has records of only five flowing wells in the county. These are near the southern boundary, and most of them are west of San Joaquin River. Only one, that on the McDermott estate, northeast of Newman, is used for irrigation. The others furnish supplies for stock.

Because of the meager development, the limits of the area within which flowing waters are to be expected has not been determined with certainty. Nor are these limits of as much importance here as

farther south in the valley, because the flowing wells will yield rather meagerly, their waters will be of poor quality generally, and the flowing-well area will be confined to a zone of low land along the axis of the valley, much of which is subject to overflow and some of which is alkaline.

The settlers along the west side—owners of fertile, alkali-free soils, capable of immense production if water could be applied to them, but practically limited under present conditions to dry crops—are as a matter of course deeply interested in the possibility of securing irrigation water from any source. The streams that flow from the west-side hills toward the valley are wet-weather streams of slight flow and can not be considered as sources of irrigation water.

The San Joaquin and Kings River canal system may be capable of slight extension when irrigation practice on the lands under it improves; but at best it can serve only a small additional acreage. It is probable that pumping systems will eventually be installed to lift water directly from the San Joaquin to apply to those west-side lands that are within 40 or 50 feet of the low-water level in the river. Pumping plants may also be installed in the lower west-side lands to pump ground waters, but the lift will be nearly as great as from the river and the water will be of inferior quality, since all of the west-side ground waters contain notable quantities of salts and some of them approach the limit of usability for irrigation.

PUMPING PLANTS.

Pumping plants for irrigation were practically unknown in this county in 1906, when this investigation was made, but one or two being in operation. They are used, however, to supply the stations of the Pacific Coast Oil Co., the railroads, and the domestic supply for the city of Modesto. Ground waters are accessible with moderate lifts throughout the west half of the east slope of the valley, and as irrigation progresses under the gravity systems and the water plane rises, their development will become increasingly desirable as a means of drainage as well as a source of auxiliary or independent irrigation supply. That intensive cultivation and careful methods will make it as practicable here as it is elsewhere in the valley scarcely needs affirmation.

QUALITY OF GROUND WATER.

Though little land in Stanislaus County is irrigated by pumping it is apparent from conditions north and south of this county that ground water of good quality can be procured from wells 100 to 1,000 feet deep in the territory indicated as east of line C′C′ in Plate II (in pocket). Those that were tested average about 300 parts per

million in total solids and 140 parts in total hardness, and nearly all are classed as good for irrigation; they would form some scale in boilers, but they are not corrosive and would not cause foaming. Waters deeper than 1,200 feet are probably salty. As no wells more than 200 feet deep on the east side of the county could be tested, the composition of the deep waters between San Joaquin River and the location shown by line C′C′ is unknown. Some of the supplies from wells 30 to 100 feet deep west and south of Modesto and close to the axis are high in chlorides, and those from wells 300 to 600 feet deep in Stevinson Colony are salty, as is also that from the 480-foot well at Crows Landing. Any artesian waters in Stanislaus County, therefore, would probably be salty and would range from fair to bad for irrigation, according to their concentration.

The west-side waters are irregular in composition, except that all contain notable amounts of sulphate. All those tested near Newman are highly mineralized sodium chloride waters of poor quality, the shallow supplies not being essentially different from those at 300 to 400 feet. Several waters with carbonate predominating were found at Crows Landing and at Westley, but they would also deposit large quantities of hard scale in boilers. No supplies that would be considered unfit for irrigation were found north of Newman, though the artesian supply near Crows Landing is of rather doubtful quality. Water from wells 80 to 300 or 400 feet deep west of the artesian area could probably be utilized for irrigation. The water from San Joaquin River is acceptable for irrigation.

Tables 40 and 41 indicate the composition and usefulness of the ground waters in Stanislaus County that were analyzed or assayed.

WELL RECORDS.

The data assembled in the following tables of wells in Stanislaus County were secured by W. N. White in 1906, and therefore do not record developments since that date.

TABLE 42.—*Records of wells in Stanislaus County.*

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water.	Temperature of water.	Method of lift.	Use of water.[a]	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	° *F.*			*Miner's inches.*		
Rhodes Bros.	Sec. 2, T. 1 N., R. 10 E.	1882	Bored, 4 inches	16	2		Wind	D, S.			$160
Henry McDevitt	Sec. 11, T. 1 N., R. 10E.	1873	Dug, 5 feet	158	152		do	D, S.			[b] 400
D. E. Kelliher	Sec. 35, T. 1 N., R. 10 E.	1892	Dug	70	65	69	do	D, S.			
Luke Nolan	Sec. 34, T. 1 N., R. 10 E.	1904	Bored, 7 inches	140	72		do	D, S.		$110	
P. L. Ford	Sec. 33, T. 1 N., R. 10 E.	1866	Dug, 4 feet	77	71.5	70	do	D, S.			125
F. L. Griffin	Sec. 32, T. 1 N., R. 10 E.	Old.	do	110	72		do	D, S.			
San Francisco Savings Bank	Sec. 10, T. 1 S., R. 10 E.	1881?	Dug	175	131		do	D, S.			
Mr. Aldrich	Sec. 18, T. 1 S., R. 10 E.	Old.	do	160	100		do	D, S.			
Mr. Spanker	Sec. 16, T. 1 S., R. 10 E.	Old.	do	125	118.2		do	D, S.			
Richard Stelck	Sec. 19, T. 1 S., R. 10 E.	1905	Bored, 8 inches	90	64		do	D, S.		52	30
R. Reid	Sec. 21, T. 1 S., R. 10 E.	1885?	Dug, 4 feet	110	100		do	D, S.			
S. F. Capps	Sec. 27, T. 1 S., R. 10 E.	1866?	do	114	106.3		do	D, S.			
H. L. Heinricks	Sec. 29, T. 1 S., R. 10 E.	1904	Bored, 2½ inches	170			do	D, S.			26
Harry Bates	Sec. 34, T. 1 S., R. 10 E.	Old.	Dug, 4 feet	100	89		do	N			
E. Williams	Sec. 6, T. 2 S., R. 11 E.		do	48	42		Hand	S.			
James McLeod	Sec. 5, T. 2 S., R. 11 E.	1882	do	276	24.1	61	Wind	D, S.		26	50
J. D. Bently	Sec. 7, T. 2 S., R. 11 E.	1871	Dug, 3 feet	165	118		do	D, S.			
	Sec. 9, T. 2 S., R. 11 E.		do	+ 75	62.5		do	D, S.			
L. C. Walter	Sec. 13, T. 2 S., R. 11 E.	1885?	do	135	128		do	D, S.			
William N. Adams	Sec. 17, T. 2 S., R. 11 E.	Old.	Dug, 4 feet	117	99		do	D, S.			
J. H. Mowry	Sec. 22, T. 2 S., R. 11 E.	Old.	Dug, 3 feet	160	149		do	D, S.			
Mrs. Kearney	Sec. 20, T. 2 S., R. 11 E.	Old.	Dug, 5 feet	140	127		do	D, S.		280	100
M. B. Root	Sec. 28, T. 2 S., R. 11 E.	1876	Dug, 4 feet	150	140		do	D, S.			107
H. D. Laughlin	Sec. 30, T. 2 S., R. 11 E.	1898	Dug, 3 feet	+100	105		do	D, S.			
E. J. Blankenship	Sec. 14, T. 2 S., R. 10 E.	1866	Dug, 5 feet	150	142		do	D, I.			
F. M. Cottle	Sec. 12, T. 2 S., R. 10 E.	1880	Dug, 4 feet	60	55		do	D, S.			
John Clark	Sec. 1, T. 2 S., R. 10 E.	Old.	Dug, 5 feet	129	120		do	D, S.			
W. C. Carmichael	Sec. 4, T. 2 S., R. 10 E.	1876	Dug, 4 feet	102	90		do	D, S.			50
J. B. Ames	Sec. 11, T. 2 S., R. 10 E.	1901	Bored, 7 inches	140	40		do	D, S.			85
J. M. Haray	Sec. 15, T. 2 S., R. 10 E.	1905	Bored, 3 inches	145			do	D			
E. F. Coleman	Sec. 17, T. 2 S., R. 10 E.		Dug, 3 feet	50	40.3		do	D			50
J. W. McHugh	Sec. 26, T. 2 S., R. 10 E.	1881	Dug, 4 feet	135	110		do	D		100	175

F. H. Heckman	Sec. 35, T. 2 S., R. 10 E.	1891	do	98	90		do	D, S, I.		140	160
R. J. McKimmon	Sec. 34, T. 2 S., R. 10 E.	1897?	Bored, 7 inches	106	75.4		do	D, S.			
O. Snedigar	Sec. 29, T. 2 S., R. 10 E.	1876	Dug, 4 feet	100	88	71	Wind and gas	D, S.			240
	Sec. 36, T. 2 S., R. 9 E.	Old.	Bored, 7 inches	75	58		Wind	S.			
T. Snedigar	Sec. 25, T. 2 S., R. 9 E.		Dug, 4 feet	+ 90	63		do	D			
M. J. Kline	Sec. 27, T. 2 S., R. 9 E.	1906	Bored, 6 inches	75	35		Hand	D		37	20
Frank Bennett	Sec. 29, T. 2 S., R. 9 E.	1906	Bored, 7 inches	48	27.7		do	D		55	12
I. S. Hughes	Sec. 30, T. 2 S., R. 9 E.	1880	Bored	80	20		Wind	D, S.		75	100
L. P. Jacobson	do	1888	Bored, 8 inches	75	35		do	D, S.		100	70
W. J. Keeley	Sec. 31, T. 2 S., R. 9 E.	1861?	Dug, 3 feet		24.5		do	D, S.			74
W. E. Strother	Sec. 26, T. 2 S., R. 8 E.	1898	Bored	84	29.5		do	D, S, I			
T. S. Hayes	Sec. 33, T. 2 S., R. 8 E.	Old.	Bored, 7 inches	26	13.9		do	D			
R. L. Miller	Sec. 32, T. 2 S., R. 8 E.	1895?	Bored, 10 inches	32	11.5		do	D		40	50
J. E. Kernan	Sec. 31, T. 2 S., R. 8 E.	1881	Bored, 7 inches	30	3.9		do	D			120
Mrs. Carson	Sec. 12, T. 3 S., R. 7 E.	1886?	do	32	7.8		do	D			
D. H. Pierson	do	1891	Bored	25	12		do	D			
J. H. Terry	Sec. 13, T. 3 S., R. 7 E.	Old.	Bored, 8 inches	85	8		do	D, I.		100	100
J. N. Nelson	do	1895?	Bored, 7 inches	58	5	69	do	D, S.			40
A. Gates	Sec. 22, T. 3 S., R. 7 E.		Bored, 6 inches	99	9.2	70	do	D, S.			
Jacob Ohm	El Pescadero (Grimes)		Bored, 7 inches	+100	49		do	D			
Mrs. J. W. Hawley	do	1886	Bored	110	16		do	D, I.		165	
Samuel Gates	Sec. 26, T. 3 S., R. 7 E.	1876	Bored, 8 inches	72	11		do	D, S.		80	150
W. G. Adams	Sec. 36, T. 3 S., R. 7 E.	1885?	Bored, 7 inches		14.6		do	D, S.			50
C. D. Butter	Sec. 29, T. 3 S., R. 8 E.		do	35	8.5	68	do	D, S.			
H. Winters	do	Old.	do	130	5.8		do	D, S.			
H. A. Bowman	Sec. 28, T. 3 S., R. 8 E.	Old.	do	36	20		do	D, S.			
John Murphy	do	Old.	do	49	12	68	do	S.			
C. M. Beckworth	Sec. 17, T. 3 S., R. 8 E.	1891?	do	85	13.5		do	D			
W. W. Bacon	Sec. 8, T. 3 S., R. 8 E.	1906	do	63	9.7	69	Gas	S, I.	25	95	250
V. B. Dale	Sec. 2, T. 3 S., R. 8 E.	1869	Dug, 5 feet	26	20.7		Wind	D			
R. W. Chappel	Sec. 1, T. 3 S., R. 8 E.	1889?	Bored, 7 inches	90	16		do	D, S.		100	
E. S. Proscott	Sec. 7, T. 3 S., R. 9 E.	1904	Bored	65	35	70	do	D, S.		32	90
Covell Bros.	Sec. 11, T. 3 S., R. 8 E.	1903	do	49	20		do	D, S.		44	50
J. T. Gish	Sec. 14, T. 3 S., R. 8 E.	1903	Bored, 7 inches	42	18					22	50
R. R. Cartwright	Sec. 13, T. 3 S., R. 8 E.	1904	Bored, 7 inches	66	9	69	do	D, S.		55	55
Mrs. Williams	Sec. 24, T. 3 S., R. 8 E.	1875?	do	50	17	69	do	D, I.			
A. Halsall	Sec. 22, T. 3 S., R. 8 E.	1903	do	56	8	70	do	D, S.			b 110
C. E. Clarke	do	1904	Bored, 6 inches	56	16		do	D, S, I		49	55
George Morgan	Sec. 30, T. 3 S., R. 9 E.	1904	Bored, 7 inches	150	14	70	do	D, S, I.			
C. C. McCarty	Sec. 31, T. 3 S., R. 9 E.	1905	(c)	98	30	72	do	D, S, I.		100	60
Modesto Water Co.	Modesto	1889		195				D			
Do	do			257	33		Electric		d 125		b 63,000
R. Woods	Sec. 28, T. 3 S., R. 9 E.	Old.	Bored, 7 inches	+ 43	32.5		Wind	D, S.			40
D. S. Christman	Sec. 32, T. 3 S., R. 9 E.	Old.	Dug, 3 feet	100	29.8		do	D			
Stanislaus County	do	1875?	Bored, 10 inches	90	30		do	D, S.			
F. A. Cressey	Modesto	1902	(e)	186	27?		Electric	D	133		10,000
Mr. McMahan	Sec. 21, T. 3 S., R. 9 E.	Old.	Dug, 3 feet	50	22		Wind	D			
Mrs. I. T. Bangs	Sec. 5, T. 3 S., R. 9 E.		Dug and bored, 8 inches.	100	29		do	D, I.			

a D, domestic; S, stock; I, irrigation; B, boilers; N, not used.
b Cost of well and equipment combined.
c Dug well 33 feet deep; three 12-inch wells 195 feet deep.
d Yield estimated or statement of owner taken.
e Dug well 32 feet deep; with 10-inch well in bottom 154 feet deep.

TABLE 42.—*Records of wells in Stanislaus County*—Continued.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	*° F.*			*Miner's inches.*		
R. Coffee	Sec. 2, T. 3 S., R. 9 E.	Old.	Bored, 7 inches	65	34.5		Wind	D, S.			
H. W. Patterson	Sec. 1, T. 3 S., R. 9 E.	1895	Dug, 5 by 5 feet	50	39.9	78	do	D, S.			$50
Cole school district	Sec. 12, T. 3 S., R. 9 E.	1886?	Bored, 7 inches	48	37.5	69	do	D			
Anna M. Halverson	Sec. 11, T. 3 S., R. 9 E.	1886	do	70	34.7		do	D, S.			
Samuel K. Anderson	Sec. 15, T. 3 S., R. 9 E.	1904	do	98	33	70	Hand	D, S.			
John Adams	Sec. 13, T. 3 S., R. 9 E.	1878	Dug, 5 feet	48	35.5		Wind	D, S.			55
W. C. Keeley	Sec. 24, T. 3 S., R. 9 E.	Old.	Bored, 7 inches	60	40		do	D, S.			
H. M. Graham	Sec. 23, T. 3 S., R. 9 E.	Old.	do	75	35		do	D, S.			
George H. Flanders	Sec. 27, T. 3 S., R. 9 E.	1905	do	74	52.8	70	Hand	D			a 95
J. A. Saferite	Sec. 28, T. 3 S., R. 9 E.	1856	Dug, 4 by 4 feet	45	35		Wind	D, S.			40
Elder Pittman	Sec. 26, T. 3 S., R. 9 E.	1903	Bored, 7 inches	120	35.7		do	D, S.		$90	85
H. T. Crow	Sec. 25, T. 3 S., R. 9 E.	1886	Bored	65	39	69	do	D, S.			
Garner school district	Sec. 30, T. 3 S., R. 10 E.		Bored, 7 inches	80	44.4		do	D			
Mary A. Torbert	Sec. 31, T. 3 S., R. 10 E.	1905	do	128	57.5		do	D, S.		115	55
G. J. Bentley	Sec. 18, T. 3 S., R. 10 E.	1904	do	92	36.7	70	do	D, S.			
F. B. Lord	Sec. 6, T. 3 S., R. 10 E.	Old.	do	90	30		do	D, S.			
A. D. Medford	Sec. 5, T. 3 S., R. 10 E.	1905	do	92			do	D		72	25
J. H. Johnson	Sec. 3, T. 3 S., R. 10 E.	Old.	Dug, 4 feet	90	78		do	D, S.			
F. H. Dinkleman	Sec. 15, T. 3 S., R. 10 E.	1898?	Bored, 7 inches	100	74	69	do	D, S.			70
Milnes school district	Sec. 9, T. 3 S., R. 10 E.		do	82	62.3		do	D			
	Sec. 33, T. 3 S., R. 10 E.	1891	do	137	97		do	D, S.			
S. Spyres	Sec. 27, T. 3 S., R. 10 E.	1904	do	106	63		do	D, S.		86	65
G. P. Schafer	Sec. 26, T. 3 S., R. 10 E.		do	125	65?		do	D, S.			70
A. Shearer	Sec. 30, T. 3 S., R. 11 E.	1876?	Dug and bored, 7 inches.	116	68.4		do	D, S.			
W. H. Palmer	Sec. 18, T. 3 S., R. 11 E.	1872	Dug	100	70		do	D, S.			
George Leclert	Sec. 4, T. 3 S., R. 11 E.	Old.		145	126		do	D, S.			
Henry Schadlich	Sec. 3, T. 3 S., R. 11 E.	Old.	Dug, 5 feet	+ 100	89.6		do	D			
T. K. Beard	Sec. 9, T. 3 S., R. 11 E.	Old.	Dug, 4 feet	130	117		do	D, S.			
Do	Sec. 17, T. 3 S., R. 11 E.	1885?	Dug, 3 feet	90	78		do	D, S.			
Charles Eardley	Sec. 20, T. 3 S., R. 11 E.	1866	Bored	90	36		do	D, S.			
S. E. Welch	Sec. 29, T. 3 S., R. 11 E.	1876	do	150	84		do	D, S.			85
J. M. Finley	Sec. 8, T. 3 S., R. 11 E.	1891?	Dug	150	90		do	D, S.			
	Sec. 28, T. 3 S., R. 11 E.	Old.	Bored, 7 inches	87	75		do	D, S.			
Alice D. Jones	Sec. 7, T. 4 S., R. 12 E.	1903	do	108	51		do	D, S.			
	Sec. 9, T. 4 S., R. 12 E.	Old.	do	190?	160		do	D, S.			
Mr. Hawkins	Sec. 16, T. 4 S., R. 12 E.	Old.	Dug, 4 feet	100	91		do	D, S.			
	Sec. 15, T. 4 S., R. 12 E.	Old.	do	85	77		do	D, S.			
Jacob Oleson	Sec. 23, T. 4 S., R. 12 E.	1886	Bored, 7 inches	186	101		do	D, S.			
Dickinson school district	Sec. 25, T. 4 S., R. 12 E.	1897?	do	+ 200	197		do	D			

I. Fox	Sec. 26, T. 4 S., R. 12 E.	1875?	do	190	159		do	D, S			
J. E. Anderson	Sec. 27, T. 4 S., R. 12 E.	1876	do	200?	151		do	D, S			175
Dolan estate	Sec. 28, T. 4 S., R. 12 E.	1885?	do	160	135		do	D, S			150
A. J. Barnes	Sec. 20, T. 4 S., R. 12 E.	1885?	do	160	139		do	D, S			90
Charles Swan	Sec. 32, T. 4 S., R. 12 E.	Old.	Dug, 3 feet	115	107		do	D, S			
W. G. Bledsoe	Sec. 36, T. 4 S., R. 11 E.	1898	Bored, 7 inches	150	110		do	D			125
J. P. Ross	Sec. 25, T. 4 S., R. 11 E.	1898	do	138	98		do	D, S		105	160
James B. Wallis	Sec. 23, T. 4 S., R. 11 E.	1906	do	122	96		do	D, S		75	170
W. W. Hall	Sec. 14, T. 4 S., R. 11 E.	1890	do	160	98		do	D, S			
Clark Bradley	Sec. 10, T. 4 S., R. 11 E.	1905	do	90	62		do	D, S			
The Grange Co	Sec. 3, T. 4 S., R. 11 E.	1891	do	110	98?		do	S.			65
Gilbert Gilbertson	Sec. 4, T. 4 S., R. 11 E.	1904	do	112	68		do	D, S			50
	Sec. 9, T. 4 S., R. 11 E.		do	111	52.5		do	D, S			
L. M. Hickman	Sec. 21, T. 4 S., R. 11 E.	1889?	Bored, 8 inches	1,600?	64.3		Not raised	N			
Do	do		do	90	65		Wind	D, S			
Do	Sec. 27, T. 4 S., R. 11 E.	1882	Bored, 7 inches	139	68		do	D, S			
Balfour, Guthrie & Co	Sec. 35, T. 4 S., R. 11 E.	1888?	do	150	135		do	D, S			
G. R. Crosby	Sec. 29, T. 4 S., R. 11 E.	1906	do	96	28		Hand	D			
A. M. Morton	Sec. 31, T. 4 S., R. 11 E.	1902	do	96	36	69	do	D, S		60	
Mr. Tomlinson	Sec. 36, T. 4 S., R. 10 E.	1885?	do	+ 42	37		Wind	S.			
James Klough	Sec. 14, T. 4 S., R. 10 E.	1890?	do		56		do	S.			
Henry Sanderson	Sec. 9, T. 4 S., R. 10 E.	1902	do	178	30		do	D, S		110	80
H. C. Baskey	do	1905	do	82	46		do	D, S		60	45
W. S. Parks	Sec. 6, T. 4 S., R. 10 E.	1898	do	200	30		do	D, S			45
The Grange Co	Sec. 9, T. 4 S., R. 10 E.	1897?	do	112	40.2		do	N		85	85
H. Hughson	Sec. 16, T. 4 S., R. 10 E.	Old.	do	62	40		do	D, S			
E. Brown	Sec. 17, T. 4 S., R. 10 E.	1903	do	72	30		do	D, S		55	75
J. McEfee	do	1905	do	38	12.3	66	Hand	D			
George Tulley	Sec. 34, T. 4 S., R. 10 E.	Old.	do	67	29.3	68	Wind	D			
J. W. Bauman	Sec. 28, T. 4 S., R. 10 E.	1905	do	98	24	68	Hand	D, S			
J. M Mackley	Sec. 32, T. 4 S., R. 10 E.	1905	Bored. 4 inches	60	20		Wind	D, S			45
C. A. Brown	Sec. 32, T. 4 S., R. 10 E.	1876?	Bored, 7 inches	60	20	67	do	D			
E. B. Foote	Sec. 31, T. 4 S., R. 10 E.	1904	do	77	16	70	do	D		60	45
B. F. Barrows	Sec. 24, T. 4 S., R. 9 E.	1903	Bored	34	18		do	D, S			
A. J. Ray	Sec. 11, T. 4 S., R. 9 E.	1902	Bored, 7 inches	130	28	69	do	D, S			
S. Zinn	Sec. 3, T. 4 S., R. 9 E.	1903	Bored, 6 inches	79	17		do	D, S		57	45
T. H. Davies	Sec. 4, T. 4 S., R. 9 E.	1901	Bored, 7 inches	36	23.9	69	do	D, S			65
J. T. Kerr	Sec. 5, T. 4 S., R. 9 E.	1902	do	128	37.5		do	D, S		104	75
James Watson	Sec. 6, T. 4 S., R. 9 E.		do	90	30+		do	D, S			100
A. L. Rutherford	Sec. 8, T. 4 S., R. 9 E.	1898	do	147	12.8		do	D, S		147	
Ceres cemetery	Sec. 4, T. 4 S., R. 9 E.	1895	do	46	10.7		do	I.			
B. B. Wilson	Sec. 14, T. 4 S., R. 9 E.	1900	Bored	89	15		Hand	D			a 100
E. P. Hatch	Sec. 22, T. 4 S., R. 9 E.	Old.	Bored, 7 inches	+33	7.1		Wind	D, S			
Mr. Gray	Sec. 15, T. 4 S., R. 9 E.	1904	do	86	6	69	do	D, S			
F. Cornwall	Sec. 17, T. 4 S., R. 9 E.	1902	do	80	11.7	69	do	D, S			
Thomas Caswell	Sec. 18, T. 4 S., R. 9 E.	1902?	Dug, 3 by 3 feet	21	13.8	68	Hand	D, S			
George Davis	Sec. 19, T. 4 S., R. 9 E.	1904	Bored, 7 inches	55	15		Wind	D, S			75
Thomas Strop	Sec. 20, T. 4 S., R. 9 E.	1906	do	90	12	69	Hand	D, S			
J. N. Butts	Sec. 28, T. 4 S., R. 9 E.	1904	do	91	8.7		Wind	D, S			
E. G. Stone	Sec. 23, T. 4 S., R. 9 E.	1901	Bored	90	6		do	D, S		70	75

a Cost of well and equipment combined.

TABLE 42.—*Records of wells in Stanislaus County*—Continued.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	*° F.*			*Miner's inches.*		
W. V. Morris	Sec. 26, T. 4 S., R. 9 E.	1905	Bored, 7 inches	84	16	69	Hand	D, S		$71	
Mrs. W. C. Elliott	Sec. 34, T. 4 S., R. 9 E.	1886?	do	57	10		Wind	D, S			
Judge Hewell	do	1882	do	55	10	69	Hand	D			
A. N. Silvera	Sec. 33, T. 4 S., R. 9 E.	1903	do	52	6.5	69	do	D			
J. L. Dunn	Sec. 32, T. 4 S., R. 9 E.	1904	do	38	7	69	do	D		35	
R. R. More	Sec. 33, T. 4 S., R. 9 E.	1886	do	54	7.5		Wind	D, S			$50
F. C. Chapman	Sec. 30, T. 4 S., R. 9 E.	1876?	do	65?	10		do	D, S			75
J. H. Courtney	Sec. 13, T. 4 S., R. 8 E.	1902?		103	15.5	68	do	D, S			
Uril Bros	Sec. 1, T. 4 S., R. 8 E.	1895?	Bored, 7 inches	90	30		do	D			50
J. C. Batchelder	Sec. 4, T. 4 S., R. 8 E.		do	65			do	D, S			
District school	Sec. 8, T. 4 S., R. 8 E.	Old.	do	42	17		Hand	D			
Union Savings Bank	Sec. 18, T. 4 S., R. 8 E.	1906	do	35?		68	Wind	D, S			50
G. W. Moore estate	Sec. 30, T. 4 S., R. 8 E.	1901?	do	50	20		do	D, S			
Ed. Brush	do		Dug, 3 feet	19	8.2		do	D, S			
O. H. Halverson	Sec. 27, T. 4 S., R. 8 E.	Old.	Bored, 7 inches	+49	17+	68	do	D, S			
Thomas Coswell	Sec. 14, T. 4 S., R. 8 E.	Old.	do	60	18.3	70	do	D			
J. M. Moyle	Sec. 26, T. 4 S., R. 8 E.	Old.	do	50	9.1	69	do	D, S			
Osman Johnson	Sec. 35, T. 4 S., R. 8 E.	1897?	do	80	9.4		do	D, S			
S. Elbrush	Sec. 34, T. 4 S., R. 8 E.	Old.	do		12.3	70	do	D, S			
Laud estate	El Pescadero (Grimes).	1868	do	45	25.5		do	D, S			
C. B. Taylor	Sec. 27, T. 4 S., R. 7 E.	1890?	Bored, 6 inches	45	10		Hand	D		75	4
Smith estate	El Pescadero (Grimes).	1881?	Bored	68	48		Wind	D, S			
Balfour Guthrie Co	do	1902?	do	130	35		do	D, S			
Welty Bros	Sec. 3, T. 4 S., R. 6 E.	1890	Bored, 8 inches	140	95		do	D, S			
Chris Nickert	Sec. 12, T. 4 S., R. 6 E.	1897	Bored, 7 inches	100	60		do	D, S			a 200
J. W. Purnell	Sec. 14, T. 4 S., R. 6 E.	1878?	Dug, 4 feet	76	71.5		do	D, S			
John Gaffery	Sec. 8, T. 4 S., R. 6 E.	1876?	Dug	180	170		do	D, S			
Frank Carpenter	Sec. 24, T. 4 S., R. 6 E.	1895	Bored, 7 inches	165	100		do	D, S			
G. W. Hamilton	Sec. 26, T. 4 S., R. 6 E.	1905	Bored, 5 inches	170	150		do	D		170	200
J. M. Hammond	Sec. 28, T. 4 S., R. 7 E.	1897	Bored, 7 inches	125	65		do	D			150
Southern Pacific Co	El Pescadero (Grimes).	1887?	Bored, 10 inches	200	54		Gas	B	6		
Mrs. E. J. McDonald	Sec. 4, T. 5 S., R. 7 E.	1881	Bored	180	80		Wind	D, S			
Charles D. Elfers	Sec. 8, T. 5 S., R. 7 E.	1892	Bored, 8 inches	180	130		do	D, S		200	230
J. M. Hammond	Sec. 10, T. 5 S., R. 7 E.	1887	Dug	110	105.5		do	D, S		110	188
Elmer H. Baldwin	Sec. 14, T. 5 S., R. 7 E.	1886	Bored, 8 inches	140		64	do	D, S, I			200
M. Rogers	Sec. 23, T. 5 S., R. 7 E.	1900	Bored, 6 inches	196	80		do	D, S		196	95
John Outhet	Sec. 26, T. 5 S., R. 7 E.	1902	do	170	50		do	D, S		160	200
Mrs. B. Morton	Sec. 36, T. 5 S., R. 7 E.	Old.	Bored, 7 inches	151	95.2		do	D, S			
Pacific Coast Oil Co.[b]	Sec. 31, T. 5 S., R. 8 E.	1904	Dug and bored, 10 inches.	223	80		Steam	B			

A. D. Elfers	Sec. 6, T. 6 S., R. 8 E.	1895	Bored, 11 inches	228	90		Wind	D, S			
Zaccarias estate	do		Bored, 7 inches	170	133		do	D, S			
Mr. Love	Sec. 5, T. 6 S., R. 8 E.	1888?	do	130	63		do	S			
L. McCauley	Sec. 8, T. 6 S., R. 8 E.	1886	do	140	65		do	S			
R. B. Marshall	Sec. 10, T. 6 S., R. 8 E.		do	100	47	67	do	S			
	Del Puerto Orestimba.	Old.	do	47	13.5		do	S			
	do		do	48	10.5		do	S			
Glenn Crow	do	1886?	Bored, 8 inches	480?	0	78	Artesian	S	Small		
Do	do	Old.	Dug, 3 feet	20	14		Wind	D, S			
B. F. McCullough	do	1903?	Bored, 7 inches	100?	13	66	do	D, S			
H. F. Hoskin	do	1898?	do	160	14.5	66	do	D, S			
Crow estate	Sec. 17, T. 6 S., R. 8 E.		do	90	84.5		do	D, S			
George Fink	Sec. 21, T. 6 S., R. 8 E.	1881?	Bored, 8 inches	+93	91		do	D, S			
G. W. McGinnis	Sec. 22, T. 6 S., R. 8 E.	1906	Bored, 7 inches	248	44.5		do	S			
J. H. Elfers	Sec. 27, T. 6 S., R. 8 E.	1889	do	90	38.3		do	D, S			
P. W. Witten	Sec. 26, T. 6 S., R. 8 E.	1900	do	120	11.7		do	D, S			
John Barber	Del Puerto Orestimba.	Old.	do	50	10	66	do	D, S			
M. V. Alvis	do	1904?		123	12	69	do	D, S			$75
	do		Bored, 7 inches	102	11		do	D, S			
Mr. Stonesypher	do		do	30	15.7		do	D, S			
S. J. Reed	Sec. 4, T. 7 S., R. 8 E.	Old.	do	82	57		do	D, S			
Simon Newman Co	Sec. 5, T. 7 S., R. 8 E.	Old.	do	160	70		do	D, S			
John Elford	Sec. 10, T. 7 S., R. 8 E.	1900	do	70	58		do	D, S			
E. E. Town	Sec. 9, T. 7 S., R. 8 E.	1883?	Dug, 4 by 4 feet	22	9.6	67	do	D, S			
A. G. Stonesypher	Sec. 17, T. 7 S., R. 8 E.	1885	Dug, 3 by 3 feet	15	9		do	D, S			
Jules Cain	Sec. 10, T. 7 S., R. 8 E.	1885?	Bored, 7 inches	73	58		do	D, S			
C. Jensen	Sec. 23, T. 7 S., R. 8 E.	1886	Dug and bored, 7 inches.	118	35.5		do	D, S			
H. E. Kinkaid	Sec. 26, T. 7 S., R. 8 E.	1892	Bored, 7 inches	96	35		do	D, S			72
Frank Dennis	Sec. 24, T. 7 S., R. 8 E.	1903	do	60?	6	78	do	D, S			
G. Savage	Sec. 19, T. 7 S., R. 9 E.	1906		60	4	65	Hand	D, S			
Newman Water Co	Newman	1888	Bored, 8 inches	398	6			D			
Do	do		do	396	6		Steam	D	7		
Southern Pacific Co	do	1887	do	392	6		Gas	B	13		
Mrs. Virginia Sherman	Del Puerto Orestimba.	1886	Bored, 7 inches	54	5	67	Wind	D, S			
Priscilla Lundy	do	1888	do	78	4		do	D, S			
A. Sado	do	Old.	do		4	68	do	D, S			
A. Barbour	do		do	150	5		do	D, S			
Simon Newman	Sec. 13, T. 7 S., R. 8 E.	Old.	do	32	13.4		do	D, S			
Newman cemetery	Sec. 14, T. 7 S., R. 8 E.	1896	do	50	32.2		do	I			
J. L. Kinnear	Del Puerto Orestimba.	1895?	Bored, 8 inches		0	76	Artesian	D, S	5		
James McDermott estate	do	1904	do	285	0	76	do	I			
B. Oleson	Sec. 7, T. 7 S., R. 9 E.	1900	Bored, 7 inches	80	5	77	Wind	D, S			75
W. H. McClintock	Del Puerto Orestimba.	1893	do	56	3.5	68	Hand	D, S			
J. J. Stevison	do	1881?	Bored, 8 inches	350?	0	73	Artesian	D, S	b 1		
McCabe Bros	Sec. 6, T. 5 S., R. 9 E.	1891?	Bored, 7 inches	45	7.2		Wind	D, S			90
M. McPhersons	Sec. 8, T. 5 S., R. 9 E.		Bored, 9½ inches	40?	3.5			N			
Wren & Co	Sec. 16, T. 5 S., R. 9 E.	1881?	Bored, 7 inches	60?	8.5		Wind	D, S			
Central school district	Sec. 11, T. 5 S., R. 9 E.	1904	do	38	8		do	D			55
D. H. Holland	Sec. 12, T. 5 S., R. 9 E.	1904	Dug, 3 feet	15	8.5	68	Hand	D			

a Cost of well and equipment combined.

b Two wells.

TABLE 42.—*Records of wells in Stanislaus County*—Continued.

Owner.	Location.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water.	Temperature of water.	Method of lift.	Use of water.[a]	Yield.	Cost of well.	Cost of machinery.
				Feet.	*Feet.*	° *F.*			*Miner's inches.*		
John Service	Sec. 12, T. 5 S., R. 9 E.	1886?	Bored, 7 inches	60	10		Wind	D, S			
A. Hecht	Sec. 14, T. 5 S., R. 9 E.	Old.	do	50	9.5	78	do	S			$50
Do	Sec. 25, T. 5 S., R. 9 E.	Old.	Dug, 3 feet	12	8		Not raised	N			
O. C. Ocken	Sec. 16, T. 5 S., R. 9 E.	1905	Bored, 7 inches	67	10	68	Hand	D		$66	
Woods estate	Sec. 20, T. 5 S., R. 9 E.	Old.		59	7.5		Wind	S			50
Charles Gier	Sec. 27, T. 5 S., R. 9 E.	1881?	Bored, 6 inches	300?	0	74	Artesian	S	3		
Do	do	Old.	Bored, 7 inches	57	6.8	69	Hand	D			
G. W. Jenkins	Sec. 26, T. 5 S., R. 9 E.	1881?	do	50	9.5	68	do	D, S			
J. T. Weakley	Sec. 25, T. 5 S., R. 9 E.	1905	do	34	9.5	66	do	D, S			
A. B. Hill	Sec. 24, T. 5 S., R. 9 E.	1905	do	20	9.2	68	Wind	D, S			
S. E. Foster	Sec. 7, T. 5 S., R. 10 E.	1885?	do	38	10.3	66	do	D, S			
S. E. Anderson	Sec. 8, T. 5 S., R. 10 E.	1902	do	40	22	67	do	D, S		30	45
W. H. Potts	Sec. 5, T. 5 S., R. 10 E.	1905	do	50	9.8	68	Hand	D			*a* 49
W. H. Thornberg	Sec. 10, T. 5 S., R. 10 E	1886?	do	99	10		Wind	D, S			
L. E. Thornberg	Sec. 9, T. 5 S., R. 10 E.	1884	do	105	11		do	D, S			
Charles Crowell	Sec. 3, T. 5 S., R. 10 E.	Old.	do	140	13		do	D, S			55
L. F. Lewis	Sec. 1, T. 5 S., R. 10 E.	1884?	Bored	46	15	67	do	D, S			45
William Paul	do	1906	Bored, 7 inches	+ 40	11.8	68	Hand	D			
Manuel J. Gomez	Sec. 11, T. 5 S., R. 10 E.	1903	do	48	8	69	do	D			
J. DeNair	Sec. 13, T. 5 S., R. 10 E.	1886?	do	32	6		Wind	D			
Crane Bros	Sec. 14, T. 5 S., R. 10 E.	1901	do	48?	4.3	68	do	S			
Gus Carlson	Sec. 23, T. 5 S., R. 10 E.	1904	do	52	7.3	69	Hand	D		42	
Edwin Johnson	do	1905	do	80	9		Wind	D, S			
Henry Lundell	Sec. 15, T. 5 S., R. 10 E.	1902	do	46	8	68	do	D, S			*a* 298
Manuel Perez	do	1905	do	50	8	68	Hand	D		30	
James S. Schenk	Sec. 16, T. 5 S., R. 10 E.	1905	do	42	6	69	do	D			
August Warren	do	1903	do	40	9		Wind	D, S			
Colony district school	Sec. 17, T. 5 S., R. 10 E.	1901?	do	60	7.5		do	D			
William Fletcher	Sec. 21, T. 5 S., R. 10 E.	1906	do	50	8	70	Hand	D			
B. F. Lane	Sec. 28, T. 5 S., R. 10 E.	1901	do	60?	6		Wind	D, S			
Mr. Bowman	Sec. 32, T. 5 S., R. 10 E.		do	28	6	69	Hand	D, S			
Ed. Hill	Sec. 4, T. 6 S., R. 10 E.	1904	do	46	7	69	Wind	D, S		46	50
J. A. Gomez	do	1904	Bored	35	6	69	Hand	D			
Mrs. Casey	Sec. 27, T. 6 S., R. 10 E.	1881?	Bored, 7 inches	60?	7		Wind	D, S			
Mr. Heney	Sec. 34, T. 5 S., R. 10 E.	Old.	do	71	8.5	68	Hand	S			
P. E. Oleson	Sec. 27, T. 5 S., R. 10 E.	1903	do	104	9	70	do	D, S			
J. E. Arthur	Sec. 25, T. 5 S., R. 10 E.	1905	do	50?	7.7	70	do	D, S			
J. N. Lester	Sec. 6, T. 5 S., R. 11 E.	1905	do	121	22		Wind	D		90	75
Santa Fe Ry. Co	do	1897	Bored, 10 inches	190	30		Steam	B	*b* 6		

Nevin Bros	Sec. 4, T. 5 S., R. 11 E.	Old.	Bored, 7 inches	+ 60	50		Wind	D, S.			
Fletcher Ryer	Sec. 8, T. 5 S., R. 11 E.	1891	do	60	50		do	D, S.			50
H. C. Hyde	Sec. 20, T. 5 S., R. 11 E.	1876?	do	90	9.2	68	do	D, S.			
Ralph Giddings	Sec. 16, T. 5 S., R. 11 E.	1881?	do	60	23		do	D, S.			
John Anderson	Sec. 20, T. 5 S., R. 11 E.	1880?	do	42	19		do	S.			
Mr. Hickman	Sec. 15, T. 5 S., R. 11 E.		do	100?	80		do	D, S.			
Do	Sec. 14, T. 5 S., R. 11 E.	1875?	do	98	88.4		do	S.			85

a Cost of well and equipment combined.

b Yield estimated or statement of owner taken.

MERCED COUNTY.

GENERAL CONDITIONS.

Merced County extends entirely across the San Joaquin Valley and thus includes both east-side and west-side territory. The gradual amelioration northward of the aridity of the south end of the San Joaquin Valley becomes noticeable at this latitude; hence, the raising of grain without irrigation, which is possible on the east side as far south as Fresno County, is usually successful on the west side in the northern part of Merced County.

Irrigation by surface water is accomplished principally by the utilization of San Joaquin and Merced rivers. The lower line of the San Joaquin and Kings River canal, which leaves the river near Mendota in Fresno County, extends entirely across the west side of Merced County and into Stanislaus County. The high-line canal of the same system also extends from the southern to within a few miles of the northern edge of the county. This irrigation work commands the larger portion of the west-side plain. The zone of unwatered land, between the high-line canal and the foothills, is relatively narrow.

The most important east-side system is the Crocker-Huffman canal, which taps Merced River about 2 miles below Merced Falls and serves an extensive section east and north of the county seat. The Stevinson-Mitchell canal heads in San Joaquin River about 14 miles southwest of Merced and commands a belt from 3 to 4 miles wide between this point and the mouth of Merced River. The principal settlement below this canal, the Stevinson Colony, is between the lower Merced and the San Joaquin.

North of Merced River, the Turlock irrigation district extends into Merced County from Tuolumne County, in which lie the greater part of the lands covered by the system. In addition to these major systems, there are a number of minor canals along the Merced River bottoms. On the whole, however, the county is thinly settled and but a small portion of it is under irrigation. Perhaps three-fourths of the valley lands are devoted to dry farming, the production of hay and grain, or to pasturage.

The territory east and north of Merced, the Plainsburg and Le Grand districts in the southeastern part of the county, much of the foothill area, and the greater part of the strip on the north side of Merced River are producing hay and grain, while the greater part of the area between the main line of the Southern Pacific Co. and San Joaquin River is in pasture. Part of this pasture land was at one time tilled, but for various reasons, among them the rise of alkali, tillage has ceased, and the lands have been returned to pasture. On the west side the strip above the canals and between them and the

hills is generally in grain from Dos Palos northward. South of Dos Palos this strip is utilized principally as sheep range.

FLOWING WELLS.

The use of ground waters, like surface irrigation, is more usual in Merced than in Madera County, although it has not as yet become extensive in either county. The total number of flowing wells in the county is between 125 and 150. The greater number of these wells are shallow, from 100 to 400 feet deep, and their yield is correspondingly small. As the most of them were drilled twenty or twenty-five years ago, not for irrigation but for domestic purposes and for stock, they fulfill the function for which they were intended. Of the 130 or 135 flowing wells of which the Geological Survey has records, but 15 are reported as used for irrigation, and even these are generally used on a small alfalfa patch or garden of but little importance. The total yield of all the flowing wells in the county is estimated at less than 8 second-feet. That large yields may be secured is indicated by the experience of the Crocker-Huffman Land and Water Co. in sinking a 2,000-foot test well for oil in the spring of 1902 in sec. 15, T. 7 S., R. 13 E. No oil was found, but this well, although near the eastern edge of the flowing well area, as indicated by the shallow developments to date, yielded what is reported to have been the largest flow in the Merced district. When the casing was pulled the flow ceased, doubtless because of leakage into the upper strata. Practically all the flowing wells in the county are south and west of Merced and Livingston and east of Los Banos and South Dos Palos. Though there are many wells of this type 250 to 700 feet deep, they are principally for stock and domestic use, as the San Joaquin and Kings River canal system supplies plenty of cheap gravity water to this district.

PUMPING PLANTS.

There are between 40 and 50 pumping plants in the county, most of them equipped with gas engines. More than half of these are used to develop irrigating waters, and the remainder are used chiefly for domestic or town supplies. Grain, fruit, alfalfa, berries, sweet potatoes, etc., are the principal crops raised by the ranchers, who use pumping plants for irrigation. They express themselves as satisfied with the results and convinced that pump irrigation in many parts of Merced County may be made highly successful.

In the Atwater and Livingston districts, as well as about Plainsburg and Le Grand, plants have already proved practicable. Throughout much of the east side, to the west, south, and east of Merced, the ground-water level is within 20 feet or less of the surface, and where

soils are favorable such accessible ground waters may be utilized to advantage in pumping operations.

Merced, like other east-side counties, includes a belt between the trough of the valley and the foothills that contains more or less alkali because of the proximity of the ground water to the surface. In certain parts of this belt the content of alkali has increased in recent years as the result of irrigation by means of gravity water supplied by the Crocker-Huffman system. In such areas, if the lands are still productive, pumping, either as an independent source of irrigation water or as an auxiliary to the gravity system, is most to be desired. It results in benefit to the community in several ways. In the first place it is a method of drainage. The water that is supplied to the land is drawn from beneath it. The tendency of the ground waters to rise with irrigation is thereby counteracted and the ground water level is kept down. In the second place there is no overuse. Each acre-foot of water developed costs a fixed sum. Under these conditions more will not be used than is needed and the usual tendency of the ground-water plane to rise with irrigation will not be manifest. Again, pumping and the use of relatively high-priced water encourages intensive cultivation and this again reduces the quantity of water necessary. Frequent cultivation and the creation thereby of a mulch at the surface has long been recognized as one of the effective means of prevention of loss of water by evaporation from the surface. Whether lands already damaged by alkali as a result of the application of too much water can be reclaimed and utilized by pumping under the economic conditions that now exist is an unsettled question; but there is no doubt that the irrigation of undamaged lands whose water plane lies within 20 or 25 feet can be carried out successfully where intensive farming methods are used, and that the rise of alkalies in such lands will be prevented.

QUALITY OF WATER.

The east-side waters from wells 15 to 700 feet deep, ranging from 100 to 600 parts, average about 200 parts per million in their content of mineral matter. Though they differ considerably from each other in concentration those away from the trough are generally calcium carbonate waters good for irrigation and good to poor for boilers. Wells 100 to 1,000 feet deep in the territory indicated as lying east of line C′C′ on Plate II would probably yield water of the character just described. No apparent general difference in quality exists between the shallow waters and those down as far as 600 or 700 feet, though local differences of some magnitude are observable. For example, comparison of analyses (Tables 43 and 44) indicates that shallow waters at Merced are poorer than the deeper ones. Water

....	N. C.	12	High......	...do......	Bad......	Fair.
Mrs. Desmarais............	N. C.	18	Moderate .	...do.......	Good......	Do.
Anna D. Ehlers............	N. C.	20	...do......	...do.......	Fair.......	Good.
Do....................	?	18	...do......	$Ca\text{-}CO_3$....	Poor......	Fair.
J. F. Chamberlain.........	N. C.	17	...do......	$Na\text{-}CO_3$...	Fair.......	Do.
Miller & Lux..............	N. C.	50	...do......	...do.......	...do.......	Good.
E. B. Fowler..............	?	80	...do......	$Ca\text{-}CO_3$....	...do.......	Do.
E. P. Tyler................	N. C.	40	...do......	...do.......	...do.......	Do.
August Tetzlaff............	N. C.	35	Low.......	...do.......	...do.......	Do.
John Furtado..............	N. C.	12	Moderate .	$Na\text{-}CO_3$...	Good......	Fair.
Do....................	N. C.	30	...do......	$Ca\text{-}CO_3$....	Fair......	Good.
California Pastural & Agric	N. C.	80	...do......	...do.......	...do.......	Do.
W. Whelan.................	N. C.	140	...do......	...do.......	...do.......	Do.
J. L. Gillette..............	N. C.	140	...do......	...do.......	...do.......	Do.
T. B. Stribling.............	N. C.	100	...do......	...do.......	...do.......	Do.
George D. Bliss............	N. C.	80	...do......	...do.......	...do.......	Do.
G. L. Hake.................	N. C.	80	...do......	...do.......	...do.......	Do.

a C., cc c Three wells 172, 292, and 320 feet deep.

Owner.		Classification.				Analyst.
		Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.	
A. J. Hulen..........	Oct.	Moderate..	$Ca\text{-}CO_3$....	Fair......	Good....	F. M. Eaton.
A. Erickson..........	Oct.	do......	$Na\text{-}CO_3$...	...do......	...do.....	Do.
Pacific Coast Oil Co..	May	High......	$Na\text{-}SO_4$....	Very bad..	Fair.....	Pacific Coast Oil Co.
Do...............	......	do......	...do......	...do......	...do.....	Do.
Do...............	May.	do......	...do......	...do......	Poor....	Do.
Southern Pacific Co..	Aug.	Moderate..	$Na\text{-}CO_3$...	Fair......	Good....	Southern Pacific Co.
Miller & Lux........	Oct.	High......	Na-Cl.....	Very bad..	Poor....	F. M. Eaton.
John Kincaid........	Oct.	do......	Ca-Cl......	Bad.......	...do.....	Do.
California Pastural & Agricultural Co.	Oct.	Moderate..	$Na\text{-}CO_3$...	Good......	Good....	Do.
Miller & Lux........	......	do......	...do......	Fair......	...do.....	Do.
Santa Fe Ry. Co.....	Nov.	do......	Ca-CO.....	Poor......	...do.....	Kennicott Water Softener Co.
Do...............	......	do......	...do......	Fair......	...do.....	Do.
Fresno Consumers Ice Co.	Jan.	High......	...do......	Bad.......	Fair.....	Smith, Emery & Co.
Do...............	......	Moderate..	...do......	Good......	Good....	Do.

; second at 95 to 220 feet depth.

TABLE 43.—*Field assays of ground waters in Merced County.*

[Parts per million except as otherwise designated.]

Owner.	Date, 1910.	Location. Sec.	T.	R.	Depth of well (feet).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total solids.	Scale-forming ingredients (s).	Foaming ingredients (f).	Probability of corrosion[a] (c).	Alkali coefficient (k) (inches).	Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.
Frank Munyan	Oct. 13	36	7 S.	8 E.	52	0	449	62	25	323	550	350	190	N. C.	19	High	$Ca-CO_3$	Poor	Good.
F. B. Fentern	do.	12	8 S.	8 E.	25	Tr.	179	146	35	250	460	280	140	?	45	Moderate	$Ca-SO_4$	do.	Do.
C. J. Warn	Oct. 26	25	6 S.	9 E.	45	0	263	Tr.	145	122	490	150	400	N. C.	6.5	High	$Na-CO_3$	Fair	Fair.
C. M. Johnson	do.	26	6 S.	9 E.	301	0	139	470	450	271	1,600	300	1,500	?	4	do.	Na-Cl	Very bad	Poor.
John Carlson	do.	36	6 S.	9 E.	32	0	54	Tr.	5	47	100	100	10	N. C.	400	Low	$Ca-CO_3$	Good	Good.
R. H. Dambauer	Oct. 13	4	8 S.	9 E.	120	Tr.	181	130	35	252	440	280	110	N. C.	50	Moderate	do.	Poor	Do.
A. G. Worthington	do.	9	8 S.	9 E.	580	Tr.	210	104	25	247	400	280	90	?	70	do.	do.	do.	Do.
J. L. Hale	do.	29	8 S.	9 E.	196	Tr.	203	113	35	240	510	270	220	N. C.	40	High	do.	do.	Do.
P. Jorgensen	do.	13	9 S.	9 E.	402	Tr.	199	100	150	229	590	200	340	?	13	do.	Na-Cl	Bad	Fair.
Ingomar school district	do.	15	9 S.	9 E.	23	0	213	100	150	368	600	400	100	?	14	do.	Ca-Cl	Poor	Do.
A. J. Hulen	Oct. 25	24	10 S.	9 E.	90	0	176	55	55	250	370	300	40	?	35	Moderate	$Ca-CO_3$	do.	Good.
George P. Oleson	Dec. 9	8	6 S.	10 E.	64	0	175	5	30	119	270	170	90	N. C.	30	do.	do.	Fair	Do.
J. J. Stevinson	Oct. 26	31	6 S.	10 E.	600	0	109	390	1,060	490	2,400	520	2,000	C.	2	Very high	Na-Cl	Very bad	Bad.
A. Erickson	do.	32	6 S.	10 E.	84	Tr.	130	Tr.	55	68	250	120	100	N. C.	16	Moderate	$Na-CO_3$	Fair	Fair.
Mrs. L. J. Stevinson	Dec. 12	6	7 S.	10 E.	330	12	146	430	320	160	1,400	190	1,270	?	4	High	$Na-SO_4$	Very bad	Poor.
D. C. Van Clief	do.	13	7 S.	10 E.	14	6	192	Tr.	20	11	260	60	250	N. C.	8	Moderate	$Na-CO_3$	Fair	Fair.
J. J. Stevinson	do.	25	7 S.	10 E.	250	0	78	260	2,080	680	3,900	710	3,500	C.	1.0	Very high	Na-Cl	Very bad	Bad.
C. W. Smith	Oct. 13	32	9 S.	10 E.	82	0	476	136	85	300	780	330	470	N. C.	8	High	$Na-CO_3$	Bad	Fair.
Woods estate	Oct. 24	9	10 S.	10 E.	45	Tr.	210	25	30	270	350	300	10	?	70	Moderate	$Ca-CO_3$	Poor	Good.
W. T. Wisenor	Oct. 25	14	10 S.	10 E.	40	6	219	96	100	265	530	300	220	?	19	High	do.	do.	Do.
A. H. Salau	do.	29	10 S.	10 E.	57	Tr.	186	38	30	207	320	260	40	?	70	Moderate	$Na-CO_3$	do.	Do.
George Waggoner	do.	33	10 S.	10 E.	50	6	142	41	30	172	290	220	50	?	70	do.	do.	do.	Do.
Miller & Lux	Oct. 30	4	11 S.	10 E.	60	0	185	25	40	184	310	230	70	N. C.	50	do.	$Ca-CO_3$	do.	Do.
S. E. Tulley	do.	13	11 S.	10 E.	40	6	160	172	120	260	630	290	300	?	16	High	$Na-SO_4$	Bad	Fair.
H. Schafer	do.	14	11 S.	10 E.	40	0	250	616	375	646	1,800	680	1,000	?	5	do.	do.	Very bad	Poor.
C. F. Kinnercan	Oct. 16	31	5 S.	11 E.	85	0	69	Tr.	30	118	160	150	10	?	70	Moderate	$Ca-CO_3$	Fair	Good.
F. M. Ecclefield	do.	23	6 S.	11 E.	65	0	100	Tr.	15	72	160	120	40	N. C.	60	do.	do.	do.	Do.
F. E. Crowell	Oct. 28	24	6 S.	11 E.	93	0	93	Tr.	15	72	150	120	30	N. C.	90	Low	do.	do.	Do.
Mrs. Hicks	do.	24	6 S.	11 E.	30	0	93	Tr.	10	40	150	90	70	N. C.	30	do.	$Na-CO_3$	Good	Do.
Southern Pacific Co.	do.	25	6 S.	11 E.	112	0	95	Tr.	15	75	160	120	40	N. C.	80	Moderate	$Ca-CO_3$	Fair	Do.
Livingston Hotel	do.	25	6 S.	11 E.	50	0	92	Tr.	15	73	150	120	40	N. C.	80	Low	do.	do.	Do.
W. C. Blewett	Oct. 16	26	6 S.	11 E.	60	0	107	Tr.	25	74	180	120	70	N. C.	40	Moderate	do.	do.	Do.
J. J. Stevinson	do.	28	6 S.	11 E.	48	0	99	Tr.	30	92	180	140	40	N. C.	70	do.	do.	do.	Do.
C. F. Blewett	Oct. 28	2	7 S.	11 E.	60	0	100	Tr.	15	67	160	120	50	N. C.	45	do.	do.	do.	Do.
George Bloss, jr	Dec. 16	17	7 S.	11 E.	330	0	80	300	1,980	640	3,800	670	3,400	C.	1.0	Very high	Na-Cl	Very bad	Bad.
Do.	do.	20	7 S.	11 E.	22	6	96	Tr.	35	25	200	80	150	N. C.	15	Moderate	$Na-CO_3$	Good	Fair.
Miller & Lux	Oct. 30	20	8 S.	11 E.	([b])	Tr.	92	328	1,520	506	3,100	540	2,800	C.	1.3	Very high	Na-Cl	Very bad	Bad.
Do.	Oct. 14	13	10 S.	11 E.	60	Tr.	178	85	330	304	840	330	530	?	6	High	do.	do.	Poor.
Do.	do.	14	10 S.	11 E.	372	Tr.	156	471	445	162	1,600	190	1,500	?	4	do.	do.	do.	Do.
J. J. Saunders	Oct. 30	10	8 S.	12 E.	297	Tr.	169	5	10	61	220	110	140	N. C.	15	Moderate	$Na-CO_3$	Fair	Fair.
Miller & Lux	Oct. 14	Sanjon de Santa Rita.			130	0	108	10	65	185	260	240	10	?	30	do.	$Ca-CO_3$	Poor	Good.
Do.	Oct. 31	1	11 S.	12 E.	375	Tr.	103	10	175	144	420	170	270	?	12	do.	Na-Cl	do.	Fair.
R. R. George	do.	10	11 S.	12 E.	23	0	123	82	595	568	1,200	600	620	C.	3	High	do.	Very bad	Poor.
John Kincaid	do.	10	11 S.	12 E.	75	0	152	52	470	505	1,000	530	400	?	4	do.	Ca-Cl	do.	Do.
Miller & Lux	do.	21	11 S.	12 E.	550	0	121	404	1,155	574	2,000	600	2,100	C.	1.7	Very high	Na-Cl	do.	Bad.
L. F. Herrod	Oct. 16	7	7 S.	13 E.	44	0	60	Tr.	10	54	120	80	10	N. C.	200	Low	$Ca-CO_3$	Good	Good.
C. J. Pregno	do.	15	7 S.	13 E.	59	0	135	Tr.	15	116	190	170	20	N. C.	140	Moderate	do.	Fair	Do.
John Rodman	Oct. 17	16	8 S.	13 E.	707	Tr.	191	Tr.	30	28	200	80	230	N. C.	9	do.	$Na-CO_3$	do.	Fair.
Crocker estate	do.	24	8 S.	13 E.	151	0	161	Tr.	10	88	200	140	80	N. C.	25	do.	do.	do.	Good.
J. F. Chamberlain	do.	9	9 S.	13 E.	20	0	315	Tr.	140	257	530	290	300	N. C.	12	High	do.	Bad	Fair.
Mrs. Desmarais	Oct. 14	13	9 S.	13 E.	252	3	111	Tr.	25	42	190	90	120	N. C.	18	Moderate	do.	Good	Do.
Anna D. Ehlers	Oct. 17	15	9 S.	13 E.	300	0	132	Tr.	25	60	200	110	110	N. C.	20	do.	do.	Fair	Good.
Do.	do.	15	9 S.	13 E.	70	0	216	Tr.	115	221	400	250	160	?	18	do.	$Ca-CO_3$	Poor	Fair.
J. F. Chamberlain	do.	21	9 S.	13 E.	340	0	150	Tr.	20	65	210	120	120	N. C.	17	do.	$Na-CO_3$	Fair	Do.
Miller & Lux	Oct. 14	Sanjon de Santa Rita.			320	3	96	5	35	51	200	100	120	N. C.	50	do.	do.	do.	Good.
E. B. Fowler	Oct. 18	36	7 S.	14 E.	50	0	142	Tr.	25	151	210	200	0	?	80	do.	$Ca-CO_3$	do.	Do.
E. P. Tyler	Oct. 17	5	8 S.	14 E.	([c])	0	142	Tr.	10	88	190	140	50	N. C.	40	do.	do.	do.	Do.
August Tetzlaff	Oct. 19	27	8 S.	14 E.	325	Tr.	132	5	10	74	190	120	70	N. C.	35	Low	do.	do.	Do.
John Furtado	Oct. 14	7	9 S.	14 E.	250	3	149	Tr.	20	34	210	80	160	N. C.	12	Moderate	$Na-CO_3$	Good	Fair.
Do.	do.	7	9 S.	14 E.	60	Tr.	179	5	35	135	270	180	90	N. C.	30	do.	$Ca-CO_3$	Fair	Good.
California Pastural & Agricultural Co.	do.	6	10 S.	14 E.	283	Tr.	102	Tr.	25	87	180	140	40	N. C.	80	do.	do.	do.	Do.
W. Whelan	Oct. 18	32	7 S.	15 E.	60	0	112	Tr.	15	102	170	150	10	N. C.	140	do.	do.	do.	Do.
J. L. Gillette	Oct. 19	24	8 S.	15 E.	18	0	126	Tr.	15	102	180	150	30	N. C.	140	do.	do.	do.	Do.
T. B. Stribling	do.	29	8 S.	15 E.	75	Tr.	174	5	20	161	240	210	20	N. C.	100	do.	do.	do.	Do.
George D. Bliss	do.	30	9 S.	15 E.	350	0	86	Tr.	25	76	160	130	40	N. C.	80	do.	do.	do.	Do.
G. L. Hako	do.	19	8 S.	16 E.	100	0	156	Tr.	25	132	220	130	40	N. C.	80	do.	do.	do.	Do.

[a] C., corrosive; N. C., noncorrosive; ?, corrosion uncertain or doubtful.

[b] Artesian well; depth not given, probably over 500 feet.

[c] Three wells 172, 292, and 320 feet deep.

TABLE 44.—*Mineral analyses of ground waters in Merced County.*

[Parts per million except as otherwise designated.]

Owner.	Date	Location. Sec.	T.	R.	Depth of well (feet).	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Scale-forming ingredients. (s).	Foaming ingredients. (f).	Probability of corrosion (c).[a]	Alkali coefficient (k) (inches)	Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.	Analyst.
A. J. Hulen	Oct. 25, 1910	24	10 S.	9 E.	90		0.05	33	19	[b]16	48	71	45	58	314	180	40	?	35	Moderate	$Ca-CO_3$	Fair	Good	F. M. Eaton.
A. Erickson	Oct. 27, 1910	32	6 S.	10 E.	84		.50	21	3.5	[b]52	Tr.	132	0	51	232	120	140	N. C.	19	do.	$Na-CO_3$	do.	do.	Do.
Pacific Coast Oil Co.	May 29, 1909	36	9 S.	10 E.	350	[c]32		72	8	310	0	179	521	139	1,170	260	840	?	10	High	$Na-SO_4$	Very bad	Fair	Pacific Coast Oil Co.
Do.		36	9 S.	10 E.	350	[c]59		66	45	323	0	266	507	220	1,351	330	870	?	7.4	do.	do.	do.	do.	Do.
Do.	May 29, 1909	36	9 S.	10 E.	660	[c]36		51	22	493	0	333	537	372	1,681	220	1,350	N. C.	4.5	do.	do.	do.	Poor	Do.
Southern Pacific Co.	Aug., 1900	25	6 S.	11 E.	97	[c]59		16	6	31	0	85	7	39	200	115	85	N. C.	45	Moderate	$Na-CO_3$	Fair	Good	Southern Pacific Co.
Miller & Lux	Oct. 14, 1910	14	10 S.	11 E.	372		1.00	38	5.8	[b]520	0	137	441	481	1,616	150	1,400	?	4.2	High	Na-Cl	Very bad	Poor	F. M. Eaton.
John Kincaid	Oct. 31, 1910	10	11 S.	12 E.	75		.40	95	52	[b]49	0	142	45	433	1,118	400	403	C.	4.7	do.	Ca-Cl	Bad	do.	Do.
California Pastural & Agricultural Co.	Oct. 14, 1910	6	10 S.	14 E.	283		.15	10	3.7	[b]25	26	24	0	22	168	85	70	N. C.	37	Moderate	$Na-CO_3$	Good	Good	Do.
Miller & Lux	do.	Sanjon de Santa Rita.			320		.25	19	2.1	[b]44	3.6	107	7.0	35	218	110	120	N. C.	22	do.	do.	Fair	do.	Do.
Santa Fe Ry. Co.	Nov. 4, 1902	19	7 S.	14 E.		[c]82		54	33	10	0	240	21	51	369	300	30	?	40	do.	Ca-CO	Poor	do.	Kennicott Water Softener Co.
Do.		17	8 S.	16 E.		[c]35		34	9	22	0	160	24	9	212	150	60	N. C.	75	do.	do.	Fair	do.	Do.
Fresno Consumers Ice Co.	Jan. 17, 1910	19	7 S.	14 E.	([d])			103	60	53	0	521	32	125	781	450	140	?	16	High	do.	Bad	Fair	Smith, Emery & Co.
Do.	do.	19	7 S.	14 E.	([d])		[e]18	21	5	3	0	78	Tr.	12	230	100	10	?	170	Moderate	do.	Good	Good	Do.

[a] C., corrosive; N. C., noncorrosive; ?, corrosion uncertain or doubtful.
[b] Computed.
[c] Including oxides of iron and aluminum.

[d] First sample at 45 to 47½ feet depth; second at 95 to 220 feet depth.
[e] Oxides of iron and aluminum.

from wells deeper than 700 feet could not be tested, but it is probable that borings more than 1,200 feet deep in the valley part of the county would yield salty or brackish water. It is reported that a 2,000-foot well in sec. 15, T. 7 S., R. 13 E., yielded soft water of fine quality, but it is probable that the water was strongly saline; no analyses of it are available, and the hole filled after removal of the casing.

Calcium carbonate waters are found along the east edge of the flowing-well area, but the supplies gradually become poorer toward the axis of the valley because of increasing predominance of the alkalies, so that many of those near San Joaquin River are poor to bad for irrigation. Artesian wells 300 to 600 feet deep in Tps. 6 S., R. 9 E.; 6 S., R. 10 E.; 7 S., R. 9 E.; 7 S., R. 10 E.; 7 S., R. 11 E.; and 8 S., R. 11 E., yield rather highly concentrated sodium chloride waters; several wells 250 to 700 feet deep southeast of those townships between Chowchilla Ranch and Merced, however, yield carbonate waters of good quality; consequently the sodium chloride waters may be considered to be confined to a belt near the axis and to be most common in the northern part of the belt. Wells 30 to 50 feet deep around the mouth of Merced River, where some of the strongest salt waters were found in deeper wells, yield good water.

Water from wells a few miles west of San Joaquin River contains appreciable amounts of sulphate, but that constituent is subordinate to carbonate in a strip extending from Newman into Los Banos Colony midway between the river and the foothills of the Coast Range. Though alkaline-earth bases are most commonly predominant, and the carbonate character of the water consequently does not spoil these waters for irrigation, they are poor for boiler use. Southeast of that area in Dos Palos Colony and the territory west of it the ground waters, being harder and higher in mineral content, are fair to poor for irrigation and bad for boiler use. The deep well at South Dos Palos yields salt water. The waters immediately northeast of Dos Palos Colony are somewhat better in quality.

WELL RECORDS.

The records upon which the following tables were based were collected by W. N. White during the early summer of 1906 and by Messrs. A. J. Fiske, jr., R. M. Priest, and S. M. Smith during the preceding autumn. It is intended to summarize in them the essential facts about each well.

TABLE 45.—*Records of wells in Merced County.*

Owner.	Location. Section.	Township south.	Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.[a]	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
Mary M. Harder	8	4	14	1877?	(*b*)	100	50	72	Wind	D, S			$70
Lucinda Fuller		4	14	1870?	Dug, 3 feet	63	59		do	D, S			
Mary M. Harder	17	4	14	1876?	Dug, 5 feet	50	46		do	S			50
San Francisco Savings Union	18	4	14	Old.	Dug, 3 feet	75	60		do	S			
Anderson school district	22	4	14	1890?	Dug, 4 feet by 4 feet	28	5.5		do	D			75
A. C. Barber	21	4	14	Old.	Dug, 4 feet	46	8½	65	Hand	D, S			
Mrs. C. Harder	30	4	14	1880?	do	58	53		Wind	D, S			
J. L. Allen	29	4	14	1903	Bored, 7 inches	106	94		do	D		$90	90
D. Wilson	33	4	14	1878	Dug, 5 feet by 5 feet	122	82.8		do	S			
D. A. Guernsey	27	4	14	1876?	Dug, 4 feet	58	42.4		do	S			90
Fred Spinker	31	4	14	1876?	Dug, 3 feet	97	91		do	D, S			
John Halverson	31	4	14	1881?	(*c*)	125	95		do	D, S			75
John Spenker	36	4	12	1880?	Dug, 5 feet	127	117.3		do	D, S			75
San Francisco Savings Union	35	4	13	1876?	do	71	55.8		do	D, S			60
Thomas Denigan	34	4	13	1865?	Bored, 7 feet	73?	54.6		do	S			
W. L. Dickenson	32	4	13	1883	Dug	150	140		do	D, S			
Caseretto estate	3	5	15	1859	Dug, 6 feet by 6 feet	27	18.3	70	Hand	D, S			
J. Ruddle	5	5	15	Old.	Dug, 3 feet	23	8		do	S			
H. G. Kelsey	5	5	15	1879	(*d*)	147			Wind	D		500	80
Sally Blake	7	5	15		Dug, 4 feet	60	40.7	70	Hand	D			
Sophia A. Irett	2	5	14	Old.	Bored, 7 inches		14		Wind	D, S			
Benjamin B. Robinson	11	5	14	1887?	do	60	27.4		do	D, S			
Eaton school district	15	5	14	1900	do	100	91		do	D			85
J. A. Robinson estate	16	5	14	1876?	Dug	134	124.2		do	D, S			65
William Youd	20	5	14	1883	Bored, 7 inches	150	120		do	D, S			
Blewett & Co.	29	5	14	1886?	Bored, 9 inches	91	70		do	D, S			
George Youd	20	5	14	Old.	Bored, 7 inches	150	120		do	D, S			
H. K. Huls	17	5	14	1868?	do	150	24		Hand	D, S			

J. P. Petersen	9	5	14	1901	Dug, 4 feet	18	12		Gas	D	e 10		
Snelling school district	4	5	14	1905	Dug	20	10		Hand	D			
Mrs. M. E. Bailey	4	5	14	1892?	Dug, 3 feet	18	11.9	65	do	D			
D. H. Grubb	5	5	14	1883	Dug, 4 feet	127	99		Wind	D			90
A. Demichelli	8	5	14	1872?	Dug, 3 feet	11	8.7	65	Hand	D			
Arthur Dale	7	5	14	Old.		40	8	66	Wind	D			
J. R. McHenry	2	5	13	1888?	Bored, 7 inches	120	65		do	D, S			
J. J. Stevinson	12	5	13	1886?	do	110	88.4		do				$100
W. J. Ferrell	13	5	13	1898	Dug, 4 feet by 4 feet	17	7.8	66	Hand	D, S			
Mrs. M. J. Little	23	5	13	1876?	Dug	60	8		do	D, S			
J. G. Ruddle	14	5	13	1880?	Dug, 4 feet by 4 feet	26	9.2	66	do	S.			
Do	10	5	13	Old.	Dug, 3 feet	14	5		Wind	D, S			
C. O. Buckley	15	5	13	1860?	Dug	15	12		Hand	D, S			
Marie Grade	27	5	13	Old.	do	10	6.5	62	do	D			
H. Borland	28	5	13	1885?	do	22	19		Wind	D, S			
Mrs. C. Ingalsbe	17	5	13	1886	Bored, 7 inches	100	50		do	D, S			90
Ingalsbe estate	25	5	12	1900	do	120	90		do	D		$100	100
G. H. Barfield	25	5	12	1882	Dug	74	58		do	D, S		60	60
R. Shaffer	36	5	12	1897	Bored, 7 inches	82	65		do	D, S		250	
Fletcher Ryer	26	5	12	1881?	do	90	83		do	D, S			
I. M. Bailey	23	5	12	1880?	do	120	116		do	D, S			100
F. Ryer	22	5	12	1881	do	120	90		do	D, S			
C. H. Blodgett	16	5	12	1876?	do	102	90		do	D, S		90	
Thomas Goodwill	21	5	12	1882	do	100	83.2		do	D, S			90
R. Gracey	28	5	12	1886?	do	120	84.1		do	D, S			
Union Trust Co	27	5	12	Old.	do	100	70.6		do	D, S			
Hall Bros	33	5	12	Old.	do	105	63.8		do	D, S			65
M. M. Rouse, renter	25	5	11	Old.	do	60	40		do	S.			
Olehan, Littlehill & Co	26	5	11	1905	(f)	52	32		Gas	N			
Do	26	5	11	1878?	Bored, 7 inches	75	32.4		Wind	S.			
John Anderson	21	5	11	1878?	do	55			do	D, S			
C. F. Kinnercan	31	5	11	1891	do	85	8.8		do	D, S			
Carl J. Lunderen	30	5	11	1903	do	84	6.4	68	do	D, S			
C. J. Swanson	36	5	10	1903	do	150	5.4	68	Hand	D			
Emil Hultman	36	5	10	1903	do	78	6	70	do	D, S			
	2	6	10	1876?	do	25	2	66	do	D, S			
Mr. Muller	3	6	10	Old.	do	50?	7.8		Wind	D, S			
Joseph Marcks	3	6	10		do	76	8		Hand	D, S			
A. Hallner	11	6	10	Old.	do	33	4.5		Wind	D, S			65
	12	6	10	1886?	do	58	10.5		Not raised	N			
August Erickson	10	6	10	1880?	do	42	7.9		Wind	D, S			
George Oleson	8	6	10	1902	do	60	6.5	68	do	D, S		34	50
G. V. Nystrom	16	6	10	1903	do	70	7	69	Hand	D, S			
E. G. Palmquist	14	6	10	1902	do	38	5.3		do	D		30	
John Anhstedt	15	6	10	1902	do	80	7	69	Wind	D, S			70
Nels Shoreen	15	6	10	1904	do	75	10	69	Hand	D		50	
C. A. Lundell	22	6	10	1886	do	265?	0	72	Artesian	S.	Small.		
Do	22	6	10	1903	do	80	7.5	69	Hand	D		55	
Gus. Sward	27	6	10	3190	do	40	10	69	do	D			g 50

a D, domestic; S, stock; I, irrigation; B, boilers; N, not used.
b Dug 54 feet and bored 46 feet.
c Dug 95 feet and bored 30 feet.
d Dug 97 feet and bored 50 feet.
e Yield estimated or statement of owner taken.
f Dug 28 feet and bored 24 feet.
g Cost of well and equipment combined.

TABLE 45.—*Records of wells in Merced County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
Mrs. H. Lundquest	27	6	10	1902	Hand	82	12		Wind	D		$65	$75
L. V. Estes	25	6	10	1902	do	86	25		do	D, S			60
Chedester Sisters	36	6	10	1896	do	66	20		do	D			50
J. A. Turner	34	6	10	1906	do	70	11		Hand	D		58	
Albert Anderson	34	6	10	1903	do	75	10.3		do	D		50	
	33	6	10	1902	do	40	10	69	do	D			
Andrew Nohling	21	6	10	1903	do	40	6.3	69	do	D, S			
O. H. Miren	28	6	10	1880?	do	83	7.8		Wind	D			
A. Erickson	32	6	10	1902	do	84	10		do	D		70	
J. J. Stevinson	31	6	10	1870	do	600?	0	70	Artesian	S	3		
J. T. Tornquist	20	6	10	1903	do	102	6	69	Hand	D		75	
K. A. Peterson	19	6	10	1903	do	33	8	69	Wind	D, S		17	50
J. P. Snigg	18	6	10	Old.	Bored, 8 inches	350?	0	73	Artesian	N			
Peter Anderson	17	6	10	1902	Bored, 7 inches	36	8	68	Hand	D, S		25	
California Alfalfa Colony Co	13	6	9	1883?	do		0	74	Artesian	S	*a* 1		
Do	24	6	9	1884	do	59	9.5	68	Hand	D, S			
John Robinson	22	6	9	1883?	do	275	0	73	Artesian	S	*a* 4		
Michel & Grossman	22	6	9	1885?	do	275?	0	73	do	D, S	*a* 4		
C. M. Johnson	26	6	9	1894	do	301	0	71	do	D, S	*a* 2		
M. Swensen	36	6	9	1904	do	32	12		Hand	D			
W. B. Beckwith	36	6	9	1886?	do	300	0		Artesian	D, S	*a* 2		
J. Nichols	27	6	9	1883?	do	300	0	72	do	S	*a* 4		
Michel & Grossman	26	6	9	1885?	do	300	0	72	do	S	*a* 3		
Archie Turner	30	6	11	1886?	do	69	29		Hand	N			
Olcese & Garibaldi	29	6	11	1903	do	68	32.5		Wind	D, S			
M. B. Sears	29	6	11	1878	do	46	30.2		do	D, S		60	100
Olcese & Garibaldi	33	6	11	Old.	do	62	32		Hand	N			
J. J. Stevinson	28	6	11	1882?	do	48	15.4		Wind	D, S			
W. P. McConnell	27	6	11	Old.	do	50	36.2		do	S			
Maussineo Aramajee	26	6	11	1906	Dug and bored	80	31		Gas	I		45	175
W. C. Blewett	26	6	11	1887	Bored, 7 inches	60	27		Wind	D, S		60	100
Hammett & Crowell	25	6	11	1904	(*b*)	72	31		Gas	I	*a* 55	175	850
Do	26	6	11	1905	(*c*)	91	31		do	I	*a* 75	200	1,000
F. M. Ecclefield	23	6	11	1886?	Bored, 7 inches	65	32		Wind	S			
Jos. Hitchcock	24	6	11		do	60	30	70	Hand	D, S			
W. P. McConnell	13	6	11	1903	do	69	57		Wind	D, S			119
	4	6	11	Old.	do	74	14		Not raised	N			

N. R. Schmidt	4	6	12	1866?		50	25		Wind	D, S			
Santa Fe Ry. Co.	99	6	12	1901?	Bored, 7 inches	100	60		Hand	D			
George Cressy	28	6	12	1881?	do	50	18		Wind	D, S			
Mrs. C. C. Crow	32	6	12	1876?	do		17		do	D, S			
W. H. Hartley	31	6	12		(d)	32	21		do	S			75
E. Gauthier	31	6	12	1876	Bored, 7 inches	78	20		do	D, S			
J. C. James	36	6	12	1903	do	42	26		Hand	D			e 50
Crocker Huffman Land & Water Co	26	6	12	Old.	do	24	21		Not raised	N			
A. G. McCoy	23	6	12	1906		65	43		Hand	D		42	
George Cressey	15	6	12	Old.		70	60		Wind	D, S			
J. S. Jones	11	6	12	1891	Bored, 8 inches	100	55	72	do	D, S		100	160
Amsterdam School district	9	6	13		Bored, 7 inches	108	66		do	D			
R. Schaeffer	20	6	13		do		22		do	D, S			
George Bloss	20	6	13		do	59	23		do	N			
W. C. Dallas	29	6	13		do	48	21		do	D, S			
L. A. Atwater	34	6	13	1880	(f)	100	33	72	do	D, S			
G. C. Jones	36	6	13		Bored, 6 inches	64	32		Wind and gas	D, S			175
B. Isenberg	19	6	14	Old.	Bored, 7 inches		75		Wind	D, S			
Mrs. Owens	20	6	14	1888	do	73	37.1		do	D, S			
D. S. Rosenbaum	18	6	14	1886	Bored	180	80		do	D, S			
Elmer Smith	21	6	14	Old.	Bored, 7 inches	200?	124.2		do	S			
McGann & Rector	30	6	14	Old.	do	112	28		do	D, S			90
John Schwinn	32	6	14	1890	do	60	30		do	D, S			
James Heggessy	32	6	14	1894	do	+100	50.5	73	do	D			50
Elmer Smith	35	6	14	1890	Bored, 8 inches	200	100	76	do	D, S			
A. Hill	2	7	14	1873	Bored, 7 inches	110	39		do	D, S			45
W. T. Nottingham	4	7	14	Old.	do	60	40		Hand	D			
E. P. Whitney	5	7	14	Old.	do	40	35.6		Wind	S			
Crocker Huffman Land & Water Co	6	7	14	1905	Dug, 4 feet	32	13		Electric	D, S, I	a 10		
E. M. Mills	8	7	14		Bored, 7 inches	34	9.6		Wind	D, S			55
A. L. Bartholomew	14	7	14	1885	Bored, 8 inches	60	18		do	D, S			
L. H. Applegate	7	7	15		Bored, 6 inches	65	20	70	do	N			
H. C. Wolfson	17	7	15	1897	do	40	20	69	do	D, S			
L. Coburn	16	7	15	1890	do	40	14	69	do	D, S			
S. Page	22	7	15		Bored, 7 inches	64	33	69	do	D, S			
G. H. Fancher	10	7	15		Bored, 6 inches	33	14		Not raised	N			
H. C. Wolfson	10	7	15		do	60	15	69	Wind	D, S			
Olcese & Garibaldi	14	7	15		do	70	30	69	do	D, S			
H. C. Wolfson	11	7	15		do	50	15		do	D, S			
Olcese & Garibaldi	12	7	15		do	65	29	68	do	D, S			
J. Cunningham	19	7	16	1894	do	30	8	70	do	S			
L. W. & J. M. Turner	29	7	16		do	25	10	70	do	S			
J. W. Mitchell estate	32	7	16		do	40	24		do	D, S			
D. Lewis	30	7	16		do	35	15	70	do	D, S			
M. Goldman	30	7	16		do	40	22		Hand	D, S			
J. Bean	25	7	15		do	+25	25	69	Wind	D, S			
Mrs. Reiley	36	7	15		do	42	23	70	do	D, S			
J. H. Pearl	27	7	15	1870	do	30	12		do	D, S			
Sophia E. Ivet	35	7	15		Bored, 7 inches	25	8.8		do	D, S			

a Yield estimated or statement of owner taken.
b Dug 30 feet and bored 42 feet.
c Dug 30 feet and bored 61 feet.
d Dug 14 feet and bored 18 feet.
e Cost of well and equipment combined.
f Two wells dug 50 feet and bored 50 feet, 7 inches in diameter.

TABLE 45.—*Records of wells in Merced County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
G. T. Farr	27	7	15	1904	Bored, 7 inches	32	14	68	Gas	D, S	*a* 2		
C. H. Fancher	28	7	15		Bored, 6 inches	30	16	69	Wind	D, S			
W. Whelan	32	7	15	1885	do	60	20	70	do	S			
E. Grimes	32	7	15	1890	do	58	21	70	do	D, S			
C. H. Fancher	29	7	15		do	30	23		Not raised	N			
D. Toal	31	7	15		do	65	22	70	Wind	D, S			
C. H. Fancher	30	7	15		Bored, 8 inches	75	20	69	do	D, S			
E. Grimes	24	7	14	1896	Bored, 6 inches	37	17	69	do	D, S			
G. H. Fancher	14	7	14	1905	Bored, 8 inches	30	12	68	Gas	D, S		$35	
W. H. Hartley	24	7	14	1890	Bored, 6 inches	38	17	68	Wind	D, S			
E. B. Fowler	36	7	14	1885	do	50	23	70	do	D, S			
E. Grimes	26	7	14		do	65	23	70	do	D, S			
R. B. Sheehy estate	33	7	14		Bored, 7 inches	35	8	71	do	D, S			
Do	31	7	14	1890?	do	81	4.8	68	do	D, S			
A. Bickford	30	7	14	1900	Bored, 6 inches	35	7?		do	D, S		35	$85
George W. Ferris	20	7	14	1903	Bored, 7 inches	73	7?		do	D, S		50	55
Santa Fe Ry. Co	19	7	14		Bored, 12 inches	56	14		Steam	B	*a* 22		
E. J. Olds	11	7	13	1875?	Bored, 7 inches		16		Wind	D, S			
Ed. Olds	3	7	13	1880	do	48	19		do	D, S			
A. J. Rodergues	5	7	13	1904	do	43	12	72	Hand	D, S		21	10
H. E. Reynolds	5	7	13	1903	do	67	18	72	do	D, S			
Jacob Feber	5	7	13	1904	do	65	13	72	do	D, S		30	7
Frank Gormen	8	7	13	1903	Bored	150	12	72	do	D, S		120	
P. Martinali	8	7	13	1904	Bored, 7 inches	35	8	72	do	D, S			
Joseph Calvez	9	7	13	1903	do	41	8	72	do	D, S		20	
Frank Duart	9	7	13	1904	do	52	7	72	do	D, S			
Buhach P. & M. Co	8	7	13	1904	Bored, 12 inches	75	12	71	Gas	I	65		*b* 1,500
Do	8	7	13	1904	do	125			do	I			
Do.*c*	8	7	13	1895	do	87	12	71	do	I	*a* 75		*b* 1,500
L. F. Herrod	7	7	13	1893	Bored, 7 inches	44	11	71	Hand	D, S			
Frank Souza	17	7	13	1899	Bored, 6 inches	64	5	68	do	D, S		24	6
Joe Fratias	8	7	13	1900	Bored, 7 inches	22	6	71	do	S			
A. J. Freieas	9	7	13	1903	do	55	8	72	do	D, S			
M. C. Raymos	10	7	13	1903	do	37	8	72	do	D, S			
Jake Rogers	10	7	13	1901	do	24	8	72	do	D, S			
Thomas Hipp	12	7	13	1904	Bored, 4 inches	50	28	72	do	D, S			
J. Beck	14	7	13	1904	Bored, 7 inches	40	10		Wind	D, S		36	50

Crocker Huffman Land & Water Co	14	7	13		do		14	68	do	D, S			50
Frank Pretis	10	7	13	1904	Bored, 8 inches	54	9		Hand	D, S		37	15
Manuel Mancebo	15	7	13	1905	Bored, 7 inches	43	6	70	do	D, S		45	4
Banks & Peterson	16	7	13		do	39	4	68	Wind	D, S		30	50
Frank Eduart	16	7	13	1902	Bored, 4 inches	38	3	68	Hand	D, S		15	4
Anton Frederico	17	7	13	1904	Bored, 12 inches	73	3		Gas	I			855
Do	17	7	13	1904	do	53							
J. F. Weber	17	7	13		Bored, 7 inches	45	6	66	Hand	D, S			
Frank Novo	16	7	13	1903	do	32	7	66	do	D, S		20	4
C. J. Pregno	15	7	13		do	59	4	68	do	D, S			
Crocker Huffman Land & Water Co	15	7	13	1902	Bored, 12 to 6 inches	2,000?	3		Not raised	N			
P. Dupont	24	7	13	1889	Bored, 7 inches	35	8		Wind	D, S		28	50
Southern Pacific Co	25	7	13	1873	Bored, 8 inches	500	3		Not raised	N			
A. E. Burnside	24	7	13	1893	Bored, 7 inches	85	6	68	Hand	D, S			
John Reininghaus	23	7	13	1900	Bored, 8 inches	23	4	68	Wind	S			50
Crocker estate	22	7	13		Bored, 7 inches	41	4		do	D, S			75
J. B. Ivers	28	7	13	1899	do	78	7	67	Hand	D, S			
H. A. Evellar	20	7	13	1899	do	43	8	68	do	D, S		20	4
H. F. Branco	20	7	13	1902	Bored, 8 inches	54	10		Gas	I			450
E. R. Vacheco	17	7	13	1904	Bored, 10 inches	95	16		do	I		56	387
J. Pimentel	17	7	13	1898	Bored, 7 inches	40	8		do	I		50	450
W. E. Mitchell	17	7	13	1901	do	50	5	67	Wind	D, S		30	
J. N. Davis	19	7	13	1904	Bored, 12 inches	45	7		Gas	I			600
W. A. Rucker	20	7	13	1900	Bored, 10 inches	59	6		do	I	a 65	41	530
Manuel Ventura	20	7	13	1904	do	67	8		do	I			300
J. N. Davis	19	7	13	1904	Bored, 12 inches	96			do	I		95	600
Do	19	7	13	1904	do	75	7		do	I			600
E. L. Stickney	24	7	12	1884	Bored, 7 inches	30	8		Wind	D, S		35	100
Julia Moran	19	7	13	1904	Bored, 10 inches	72	8		Gas	I	a 100	59	500
Frank Frago	30	7	13	1891?	Bored, 7 inches	52	9		Wind	D, S			60
J. S. Balerio	20	7	13	1901	Bored, 8 inches	68	5		Gas	I		60	700
R. E. Lee	29	7	13	1891?	Bored, 7 inches	47	4	72	Hand	D, S			
P. Boland	30	7	13	1901	do	24	4		do	S		13	
J. B. Ivers	21	7	13		do	32	4	67	do	S			
	27	7	13		Bored, 12 inches	56	5		Gas	I			
J. G. Crowder	36	7	13		Bored, 7 inches	34	4	68	Hand	D, S			
Mrs. W. B. Turpen	26	7	13	1896	Bored, 6 inches	40	5	68	Wind	D, S			
N. Freits	27	7	13	1890	Bored, 7 inches	30	10	68	Hand	D, S			4
Peter Underveill	36	7	13	1901	do	19	4.9	67	Wind	D, S			50
William Thornton	34	7	13	1885	Bored, 8 inches	33	7	68	Hand	D		10	4
William Hoffknecht	33	7	13	1895	Bored, 7 inches	45	5	68	do	D, S		22	4
Do	32	7	13	1903	Bored, 10 inches	46	7		Gas	I	a 90	40	700
Joseph Sullivan	33	7	13	1885	Bored, 7 inches	23	7		Not raised	N		28	
	27	7	12	1904?	do	300?	0	72	Artesian	S	4		
J. M. Haile	26	7	12	1899?	do	55	9?		Hand	D, S			
L. H. Applegate	23	7	12	1890?	do	60	8		Wind	S			
J. S. Avila	12	7	12	1897	Bored, 6 inches	50	8		Hand	D, S			
J. B. Osborn	12	7	12	1890?	Bored, 7 inches	80	10		Wind	D, S			
Heber Foster	1	7	12	1891	Bored	70	20	72	do	D, S			

a Yield estimated or statement of owner taken.

b Cost of well and equipment combined.

c Two wells.

TABLE 45.—*Records of wells in Merced County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Quantity of water.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
W. B. Mitchell	1	6	12		Bored, 7 inches	25	9		Hand	D			
Manuel Mandonca	1	7	12	1902	Bored, 9 inches	50	12	71	Gas	I			*a* $460
Dell Dotto	1	7	12		Bored, 7 inches	67	9	71	Hand	D			
W. H. Osborn	2	7	12	1895	do	54	20	71	Wind	D, S		$25	58
W. S. Crockett	2	7	12	1900	do	57	8	71	Hand	D, S			
Martha Frager	11	7	12	1900	do	54	8	70	do	D, S			
Frank Goulart	11	7	12	1900	do	65	8	71	do	D, S		35	8
E. Gauthier	5	7	12	Old.	do	50	19		Wind	D, S			
W. O. Robinson	7	7	12	Old.	do	43	13		do	D, S			
Mitchell estate	22	7	12	1878	Bored, 9½ inches		0	72	Artesian	S	*b* 1		
W. C. Dallas	22	7	11	Old.	Bored, 7 inches	275?	0	73	do	S	*b* 3		
C. F. Blewett	2	7	11	1900?	Bored, 10 inches	60	19		Gas	I	*b* 35		*a* 1,000
Crane Bros	3	7	11	1881?	Bored, 7 inches	60	15		Wind	D, S			
Mr. Webster	9	7	11	1902	do	42	13		do	D, S			
G. S. Bloss, jr	9	7	11	1892?	do	300?	0	73	Artesian	N	Small.		
Do	16	7	11	Old.	do	25	9.7		Hand	D			
Crane Bros	22	7	11	1906	do	250	0	72	Artesian	S	9		
G. S. Bloss, jr	21	7	11		do	22	5		Not raised	N			
Do	21	7	11	1905	do	338	0	73	Artesian	D, S	7		
Do	20	7	9	Old.	do	10	4.5		Not raised	N			
Do	33	7	11	1893?	Bored, 8 inches	328	0	73	Artesian	S	9		
Crane Bros	3	8	11	1881?	Bored, 7 inches	300	0	73	do	S	4		
J. J. Stevinson	25	7	10	1870	do	250	0		do	S	Small.		
D. C. Van Cleef	13	7	10		Bored, 1½ inches	14	4		Hand	D			
J. J. Stevinson	11	7	10	1870	Bored, 7 inches	250	0	74	Artesian	N	*b* 2		
S. W. Brannon	11	7	10	1898?	do	17	4	62	Hand	D			
S. B. McCollough	14	7	10	1904	Bored, 1½ inches	14	6		do	D, S			
J. J. Stevinson	16	7	10	1903	Bored, 7 inches	256	0	73	Artesian	D, S			
Do	5	7	10	1870	do	330	0		do	S	*b* 4		
Do	7	7	10	1870	do	330	0	74	do	S	*b* 6		
Do	6	7	10	1870	do	330	0	73	do	D			
Do	7	7	10	1870	do	330	0	73	do	S	Small.		
J. J. Rhea	30	7	9	1898	do	22	8		Wind	D, S		30	65
J. K. Boulware	30	7	9	1897	do	160	8.8		do	D, S			45
Pacific Coast Oil Co. *c*	28	7	9	1902	Bored, 8 inches	180	3		Steam	B			
P. Jeffson	32	7	9		Bored, 1½ inches	22	6	71	Wind and hand	D, S			
Frank Munyan	36	7	9	1904		52	12		Wind	D, S		46	45
Hubbard & Carmichael *c*	6	8	9	1892	Bored, 8 inches	42	17.5		Steam and wind	D			

F. B. Fentern	12	8	8	1901	Bored, 7 inches	25	11?		Wind	D, S			
R. H. Bambour	4	8	9	1896	Bored, 7 inches	120	4		do	D, S			
Bozeena & Steinberg	5	8	9	1888	Bored, 8 inches	500?	0		Artesian	D, S			
H. Sorensen	9	8	9	1905	Bored, 7 inches	60	4.2	68	Wind	D, S			
A. G. Worthington	9	8	9	1887?	Bored, 8 inches	580	0	77	Artesian	D, S		1,500?	
Simon Newman Co	12	8	8	Old.	Bored, 7 inches	+ 50	12		Wind	D, S			
Peter Bladt	14	8	8	1892	do	175	50?		do	D, S			
A. L. Hansen	14	8	8	1902	Bored, 8 inches	70	48.5		do	D, S		75	93
Simon Newman Co	15	8	8	1896?	Bored, 7 inches	125	20		do	D, S			
Major Eaches	22	8	8		do	125	70		do	D, S			
W. T. Bradley	28	8	8	1905	do	39	8		Hand				
E. L. Sturgeon	25	8	8		do	60	25	68	do	D, S			
William Bunker	20	8	9	1901	do	100?	9		Wind	D, S			
Woods estate	21	8	9		do	80	3		do	D, S			
B. F. Valliar	21	8	9	1896?	do	120	1		do	D, S			
Simon Newman Co	28	8	9	1887?	Bored, 10 inches	400?	0	77	Artesian	S	b 4		
H. T. Hauser	28	8	9	1906	Bored, 7 inches	111	4		Not installed				
J. L. Hale	29	8	9		Bored, 8 inches	196	10		Wind	D, S		375	122
M. L. Hunt	32	8	9	1895?	Bored, 8 inches	+300	1		Not raised	N			
Clarence Draper	31	8	9	1898?	Bored, 7 inches	173	15	71	Wind	D, S			
A. H. McBride	6	9	9	1902	do	21	13.1		Hand	D, S			
Charles Flick	32	8	9	1901	do	64	10		Gas	D, S			
H. T. Tilton	33	8	9	1890?	Bored, 8 inches	400	0	78	Artesian	S	b 2		
Simon Newman Co	3	9	9	1900	Bored, 7 inches	130	.7		Wind	N			
Do	11	9	9	1889?	Bored, 9½ inches	400?	0	78	Artesian	S	22	700	
Drummond & Page	9	9	9	1890?	Bored, 8 inches	430	0	77	do	S	Small.		
Ingomar school district	15	9	9		Bored, 7 inches	23	5.3		Hand	D	6		
P. Jorgensen	13	9	9	1891	Bored, 8 inches	402	0	78	Artesian	I		850	
Roger Fahy	27	9	9	1906	Bored, 8 inches	44	6		Wind	D, S			
Eugene McCabe	31	9	9	1905	Bored, 7 inches	60	12?		do	D, S			
John Bareiles	1	10	9	1894	do	175	7?		do	D			
N. Bibby	31	9	10	1890	Dug, 3 feet	25	5		Hand	D, S			
C. W. Smith	32	9	10	1902	Bored, 7 inches	82	4		Wind	D, S			a 200
Pacific Coast Oil Co	36	9	10	1904	Bored, 10 to 7 inches.	750	0	79	Artesian	N	b 20		
Miller & Lux	12	10	10	1901	Bored, 7 inches	42	8		Wind	S			
Woods estate	8	10	10	1905	Bored, 6 inches	24	6		do	D, S		20	75
Miller & Lux	15	10	10		Bored, 1½ inches	15	8	62	Hand	D, S			
Woods estate	9	10	10	1906	Bored, 6 inches	45	6		Wind	D, S		40	
Southern Pacific Co	14	10	10	1888?	Bored, 8 inches	375	0?		Gas	B			
Miller & Lux	14	10	10	1891	do	325	0		Steam	D			
Do	23	10	10	1903	Bored, 7 inches	60	4?		Wind	D, S			
Benjamen Orognen	22	10	10		do	25	6		Wind and hand	D, S			
Miller & Lux	21	10	10	1895	do	40	3.4		Wind and horse	D			
M. Becker	19	10	10		Dug	12	8		Hand	D			
A. J. Hulen	24	10	9	1890	Bored, 7 inches	90	5		do	D, S			
H. F. Salau	19	10	10		do	30	8		Wind	D, S		45	60
A. H. Salau	29	10	10		do	21	7		Hand	D			
C. H. Waggoner	29	10	10	1870	Bored, 10 inches	50	11?		Wind	D, S			60
W. J. Jameson	21	10	10			80	7		do	D, S		80	35

a Cost of well and equipment combined.

b Yield estimated or statement of owner taken.

c Two wells.

TABLE 45.—*Records of wells in Merced County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
J. L. Jameson	28	10	10	1899	Bored, 7 inches	30	8		Wind	D, S			
Emma Smith	27	10	10		Bored, 5 inches	30	5		do	D, S		$12	$35
C. P. Smith	23	10	10	1898	Bored	42	5?		do	D, S			*a* 100
Joe Waggoner	25	10	10	Old.	Bored, 6 inches	30	3		do	D, S			
W. M. Phillips	25	10	10	1898	do	25	10		do	D, S			*a* 200
George Blakeley	26	10	10		do	45	8		do	D, S			*a* 100
C. J. Welch [b]	35	10	10			39	8.2		Gas and wind	D		38	150
Mr. Chappel	34	10	10	1902	Bored, 7 inches	42	10		Wind	D, S			
George Waggoner	33	10	10	1866?	do	50	20		do	D, S			85
J. H. Wisenor	33	10	10	1856	Dug, 4 by 5 feet	50	23		Hand	S			
C. G. Acker	33	10	10	1876	Dug, 4 by 4 feet	50	30		Wind	D, S			*a* 150
G. D. Soper	5	11	10		Dug, 3 by 3 feet	80	13		Hand	D, S			
Miller & Lux	4	11	10	1894	Dug, 3 by 4 feet	60	52		do	S			
Do	3	11	10	Old.	Dug, 4 by 4 feet	28	22		do	D, S			
George Costen	11	11	10		Dug	20	12	66	Wind	D, S			
H. Hansen	12	11	10	1904	Dug, 3 by 3 feet	20	8	65	Hand	S			
Watkins Bros	11	11	10		Dug	180	45		Wind	D, S			35
G. J. Abeling	9	11	10		do	70	60		do	D, S			
U. G. Foat	31	11	10	1895	Bored, 7 inches		60		do	D, S			
J. L. Williams	15	11	10		Dug	86	78		do	D, S			65
J. O. Whiting	15	11	10	1905	Dug, 7 by 7 feet	83	70		Steam	I	55	175	1,000
W. T. Cheatham	23	11	10	1885?	Dug	80	60		Wind	D, S			
Alphonso	14	11	10		Bored, 7 inches		4		do	D, S			
S. E. Tulley	13	11	10		Dug, 4 by 5 feet	40	27		do	D, S			60
E. A. Scharnhorst	17	11	11		Dug	14	1.5		Hand	D, S			
Mr. Jameson	20	11	10		do	12	3		Wind	D, S			
Henry Miller	19	11	11	1900	Bored, 7 inches	45	13		do	D, S			
Do	19	11	11		Bored, 5 inches	300	5						
Do		11	10	1885?	Dug, 4 by 4 feet		80		Wind	S			
Miller & Lux	14	10	11	1905	Bored, 6 inches	372	0	+72	Artesian	D, S	2	700	
Do	13	10	11	1905	Bored, 5 inches	373	0	+72	do	S	3	700	
Do	13	10	11	Old.	Dug	60	12	69	Horse	D, S			
Do	16	10	12	1902	Bored, 6 inches	140	10?		Wind	D, S			
Henry Miller	Sanjon de Santa Rita.				Bored, 7 inches	130	8		do	D, S			
Do	do				do	350?	0		Artesian	S	Small.		
Do	do				do	350?	0	70	do	D, S	do		
Do	do				Bored, 8 inches	350	1		Horse	S			

N. W. More	34	10	12	1905	Bored, 1½ inches?	20	12	66	Hand	D, S			
John Walder	33	10	12	1902	do	15	9	64	do	D, S			9
J. L. Vaught	34	10	12	1906	Bored, 5 inches	76	12	66	do	D, S		56	
H. E. Goodwin	33	10	12	1906	Bored, 6 inches	72	10		Wind	D, S			
P. O. Baldwin	3	11	12	1902	Bored, 4 inches	78	10		do	D, S			
J. A. Fisher	3	11	12	1905	Bored, 5 inches	42	7		do	D, S		40	45
Miller & Lux	1	11	12			375	0		Artesian	D, S			
C. A. Bibler	10	11	12	1905	Bored, 6 inches	75	5		Wind	D, S		75	40
R. R. George	10	11	12		Bored, 1½ inches	23	8	67	Hand	D, S		10	
F. A. Bennett	11	11	12	1896	Bored, 5 inches	73	8		Wind	D		56	50
Joseph Walker	10	11	12		Bored, 1½ inches	20	6	65	Hand	D, S			
H. J. Quivey	15	11	12	1903	do	17	5	63	do	D, S			
E. Sorg	14	11	12		Dug, 3 by 3 feet	20	9	62	do	D, S			
Miller & Lux	21	11	12	Old.	Bored, 8 inches	550	0	76	Artesian	S	Small.		
Do	22	11	12	1891	do	550	0	76	do	S	2		
G. H. Drakley	4	8	12	1876?	Bored, 7 inches	270	0	72	do	I, S	c 3	300	
O. B. Randall	4	8	12	1881?	do	240	0		do	I	10	250	
Mrs. F. E. Turner	4	8	12	1877?	do	270	0	72	do	D, S	5	325	
School district	3	8	12	Old.	do	35	6.7		Wind	D			
J. T. Lander	3	8	12	1877	do	206	0		Artesian	I	c 3	250	
J. J. Sanders	2	8	12	1879	do	275	0	73	do	D, S	c 2	300	
Do	10	8	12	1879	do	275	0	73	do	D, S	c 4	300	
John Lander	4	8	12	1886?	do	275?	0	72	do	D, S	6		
Mrs. F. E. Turner	4	8	12	Old.	do		0	73	do	S	1		
J. J. Sanders	9	8	12	1877	do	285?	0	72	do	D, S	3		
Do	10	8	12	1879	do	297	0	73	do	D, S	c 2		
Do	15	8	12	1878	do	260	0	73	do	D, S	c 1		
Do	15	8	12	1879	do	250	0	74	do	S	6		
William Sharon estate	24	8	12	Old.	do	200	0	74	do	S	c 1		
Miller & Lux	36	8	12		do		0	74	do	S	6		
Mrs. Croop	32	8	13	1886	do	300?	0	74	do	S	Small.	300	
Stockton Savings Association	30	8	13	1888?	do	300?	0		do	D, S			
O. E. Gribi	20	8	13	1883	do	200	0	73	do	D, S	c 1	250	
William A. Saunders	19	8	13	Old.	do	200?	0		do	S	Small.		
C. H. Dean	6	8	13		Bored	60	9	68	Wind	D, S			
John Pilger	4	8	13		Bored, 8 inches	60	5	67	Hand	D, S			
Mr. Johnson	4	8	13		Bored, 7 inches	42	5	65	do	D, S			
Mr. Mitchell	3	8	13		do	37	5	67	do	D, S			
Crocker Huffman Land & Water Co	3	8	13	1890?	Bored, 8 inches	685	0	76	Artesian	S	3		
W. H. Hartley	1	8	13	1904	do	275	0	76	do	D, S, I	c 2	300	
Crocker Huffman Land & Water Co	9	8	13	1905	do	250?	0	75	do	D, S, I	4		
John Roduner	16	8	13	1894?	Bored, 9 inches	707	0	75	do	I	7		
Do	16	8	13	Old.	Bored, 8 inches	250?	0	74	do	S	Small.		
S. M. Pate	21	8	13	1903	Bored, 12 inches	96	11		Gas	I	c 90	100	1,100
Do	21	8	13	1882	Bored, 7 inches	146	0	73	Artesian	D, S	Small.		
Crocker estate	24	8	13	1886?	do	151	0	74	do	S	Small.		
School district	24	8	13		do	35	7	70	Hand	D			
M. Rahilly	23	8	13	1886?	do	160	0	72	Artesian	S	c 2		
Do	26	8	13	1887?	Bored, 9½ inches	750	0	74	do	S		1,100	

[a] Cost of well and equipment combined.

[b] Two wells.

[c] Yield estimated or statement of owner taken.

TABLE 45.—*Records of wells in Merced County*—Continued.

Owner.	Location. Section.	Location. Town-ship south.	Location. Range east.	Year com-pleted.	Type and diameter of well.	Depth of well.	Depth to water level.	Tem-pera-ture of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of ma-chinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
M. Rahilly	27	8	13	1890?	Bored, 7 inches	280	0	72	Artesian	D, S	Small.		
Do	26	8	13			135	0		do	N	*a* 2		
Williams Collins	25	8	13	1885?	Bored, 7 inches	149	0	72	do	D, S, I	*a* 2		
Mrs. E. H. Brouse				1890?	do	228	0		do	D, S			
Patrick McNamara	19	8	14	1906	do	109	0		do	D, S	*a* 2		
Do	20	8	14	1873?	do	116	1.5	73		S	Small.		
Do	19	8	14	1880?	do	120	0	74	Artesian	S	Small.		
M. Rahilly	18	8	14	1886?	do	175	0	74	do	D, S		$199	
George Minges	7	8	14	1905	do	170	0	74	do	S	Small.	200	
Do	7	8	14	1905	Bored, 10 inches	117	10		Gas	I			
Pacific Improvement Co	4	8	14	Old.	Bored, 7 inches	30	4		Wind	D, S			
Do	3	8	14		Bored, 6 inches	45	10	71	do	D, S			
E. F. Mugler	12	9	14		do	50	12	71	do	D			
William Campbell	11	8	14		Bored, 12 inches	90	12		Gas	I		23	$500
E. T. Givens	14	8	14		do	200	13		do	I			
Olcese & Croop	9	8	14	1903	Bored, 7 inches	60	4.5		Wind	S			65
James C. Chamberlain	16	8	14	Old.	Bored	40	4	68	do	D, S			
August Tetzlaff	27	8	14	1881?	Bored, 7 inches	325	0	74	Artesian	D, S	*a* 1	375	
Do	27	8	14	1906	Bored, 8 inches	344	0	74	do	S	*a* 2	500	
Do	28	8	14		Bored, 7 inches	30	4		Wind	N			
W. A. Aldrich	25	8	14	1896	do	90	0		do	D, S			
P. Carroll estate	6	8	15		Bored, 6 inches	44	17	70	do	S			
P. Sheehy estate	5	8	15		do	58	18	70	do	D, S			
Mrs. L. P. Twichell	3	8	15		Bored, 7 inches	30	12	70	do	S			
M. C. Burchell	1	8	15	Old.					do	D, S			
Do	1	8	15		Bored, 7 inches	8	4.5		Not raised	N			
R. M. Burchell	11	8	15	1897?	do	60?	12		Wind	D			85
S. L. Ritchie [b]	13	8	15	1905	Bored, 10 inches	275	18		Gas	I		600	725
J. Vetterly	13	8	15	1906	do	200	16.5						
Do	13	8	15	1900	Bored, 7 inches	160	20		Wind	D, S			
M. A. Poor	10	8	15	1893	Bored, 6 inches	32	14	71	do	D, S			
E. D. Kahl	9	8	15		do	35	15		do	D, S			
A. S. Kahl	9	8	15		do	+30	+14	70	do	D, S			
A. W. Moreley	8	8	15		Bored, 7 inches	40	16	71	do	D, S			
L. M. Helmer	7	8	15		do	30	13	71	do	D, S			
Mrs. L. P. Twitchell	7	8	15		Bored, 6 inches	28	15		do	D, S			
Joseph Vasche	18	8	15	1899	Bored, 7 inches	30	12		do	D, S			90
Do	20	8	15	1888	do	30	6?	68	do	D, S		30	90
George L. Vetterly	20	8	15	1904	do	65	8		do	D, S		70	90

J. M. Cunningham	21	8	15	1901	do	60	8		do	D, S			75
S. Hein	16	8	15	1881?	Bored, 6 inches	75	11	68	do	D, S			
E. L. Morley	15	8	15	1886?	Bored, 7 inches	100	9		do	D, S			
Lee Fancher	23	8	15	Old.	do	40	10		do	D, S			
J. L. Gillette	24	8	15	1892	do	18	13		do	D, S		20	80
Paul Newman	13	8	15	1876?	do	60	13		do	D, S			
Do	24	8	15	Old.	do	22	10		do	D, S			
T. B. Stribling	29	8	15	1880	do	75	9		do	D, S		100	90
E. D. Hollister	29	8	15	1879	do	60	8		do	D, S			120
Mrs. Fischer	31	8	15	Old.	do	55	5		do	S.			
M. M. Ritchey	35	8	15	1890	do	49	16		do	D, S			
Do	35	8	15		do	50?	12		do	S.			50
C. C. Clausen	35	8	15	1884	do	39	13.9		do	D, S			
E. W. Harrison	31	8	16	Old.	do	32	12.8		do	S.			65
N. O. Miller	30	8	16	1891	do	33	11		do	D, S			55
Paul Newman	19	8	16	1890?	do	100	10.2		do	S.			
G. L. Hake	19	8	16	1902	do	100	16.5		do	I.		90	125
Santa Fe Ry. Co.	17	8	16	1898	Bored, 10 inches	198	12		Steam	B	9		
J. S. Mitchell	16	8	16	1902	Bored, 7 inches	150	12		Wind	D, S		85	70
I. Diffin	16	8	16	1900	Bored	50	12	65	do	S.		45	
W. Wolsey	10	8	16	1886	Bored, 7 inches		12?		do	D, S			
R. H. Wallis	11	8	16	1888	Dug	15	12.5		do	D, S			65
John Baker	11	8	16		Bored, 7 inches	40	17	70	do	D, S			40
C. A. Phenegar	24	8	16	1902	do	54	8		do	D, S			75
J. W. Stevens estate	23	8	16	1902?	do	120	16?		do	D, S			75
A. J. Martin	15	8	16	1904	do	160	16	70	do	D, I.		85	
G. L. Gillette	21	8	16	1895	do		12?		do	D, I.			
Ah See	20	8	16		Bored, 10 inches	90	12		Gas	I.	a 10		
J. F. Jones	20	8	16	1903	Bored, 7 inches	90							
Do				1903	do	120	12		Steam	N.			
G. L. Hake	19	8	16	1898	do	24	13.5		Wind	D, S			40
Jacob Ipsen	20	8	16		do	22	14	69	do	D, S			c 110
D. W. Eno	28	8	16	1903	Dug, 30 inches	24	16.8	69	do	D, S			60
R. Earl	29	8	16	1884	Bored, 7 inches	30	11.2		do	D, S		25	70
E. W. Harrison	31	8	16		Dug, 3 feet	17	13.5		Hand	S.			
C. Dooley	33	8	16	Old.	Bored, 7 inches	30	12.3		Not raised	N.			
A. A. Hansen	27	8	16	1903	do	57	21		Wind	D, S, I.		12	50
Joe King	27	8	16		do	70?	30		do	D, S			85
Mr. Underwood	36	8	16	Old.	do	80	25		do	N			
C. A. Phenegar	18	8	17	1904	do	184	15		do	S		156	50
Adam Schinn estate	20	8	17	1906	do	140	3?		do	S		75	
Do	21	8	17	1846	Dug, 3 feet	10	7.2		do	D, S			45
J. J. Jones	34	8	17	1858?	Dug	67	14		do	D, S			57
Mrs. J. Murdock	28	8	17	Old.	Bored, 7 inches	76	35.5		do	D, S			45
J. Baxter	32	8	17	1899	do	75	40		do	S.			
James Kern	4	9	16	Old.	do	50?	30		Wind and horse	D, S			40
Jonathan Fancher	2	9	15	1886	do	100	14		Wind	D, S			45
M. A. McCloskey	3	9	15	1891	do	56	10.5		do	D, S		42	45
Hayes & Co.	5	9	15	1881	do	75	6		do	D, S			

a Yield estimated or statement of owner taken. b Two wells. c Cost of well and equipment combined.

TABLE 45.—*Records of wells in Merced County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
Bliss Bros	29	8	15	1875?	Bored, 12 inches	350	0	72	Artesian	S	*a* 4		
Do	30	8	15	1880	Bored, 8 inches	350	0	71	do	S	*a* 2		
F. I. Frietes	2	9	14		Bored, 7 inches	50	10	69	Hand	S		$50	
Do	3	9	14	1904	do	191	0	74	Artesian	D, S	Small.	250	
Mr. Lord	4	9	14	Old.	do		0	74	do	S	*a* 1		
John Furtado	8	9	14	Old.	Bored, 8 inches	250?	0	74	do	S	*a* 2		
Lillie Brouse	5	9	14	Old.	Bored, 7 inches		0		do	S	*a* 1		
John Furtado	7	9	14	1895?	do	250?	0	74	do	S	*a* 1		
Do	7	9	14	1903	do	60	6.6	68	Wind	D			
California Pastural & Agricultural Co	20	9	14		do		0	72	Artesian	S	Small.		
Bliss Bros	23	9	14	1875	do	250	0	72	do	S	*a* 3		
Do	26	9	14	1875?	Bored, 8 inches	350?	0		do	S			
Do	28	9	14	1875?	do	275	0		do	S	Small.		
California Pastural & Agricultural Co	20	9	14	1900	Bored, 7 inches	273	0		do	S	2		
Do	5	10	14	Old.	Bored, 6 inches	155	0	68	do	S			
Do	6	10	14	Old.	do	283	0	70	do	D, S	1		
Jose Frietes	1	9	13	1903	Bored, 7 inches	207	0		do	I	*a* 2		
Do	1	9	13	1871	do	225	0	74	do	I	Small.		
T. S. Howell	1	9	13	1878?	do	300?	0	74	do	D, S	1		
Mr. McNeil	2	9	13		Dug	16	9		Wind	D, S			
L. H. Silman	2	9	13	1876?	Bored, 7 inches	230	0	73	Artesian	I	Small.	300	
Mr. Rogers	11	9	13	1881	do	150	0	74	do	S	Small.		
Anna Silman	10	9	13	1886?	do	230	0	74	do	S	Small.		
Bowman & McGarr	3	9	13	1903	do	230	0		do	S	*a* 3		
Silas Bowman	4	9	13	1886	do	320	0	74	do	S	*a* 1		
M. E. Wasson	4	9	13	1892	do	292	0	74	do	I	*a* 1		
Silas Bowman	4	9	13	1894	Bored, 9 inches	698	0	73	do	S, I	12		
L. L. Wolfsen	5	9	13	1884	Bored, 7 inches	300	0	74	do	S	5		
Miller & Lux	2	9	12	Old.	Bored, 6 inches	32	8.7		Not raised	N			
Do	2	9	12		do		0	74	Artesian	S	15		
Do	12	9	12	Old.	Bored, 7 inches		0		do	S			
Mrs. K. Kocher	7	9	13	1885?	do	290	0	74	do	S	3	300	
L. L. Wolfsen	6	9	13	1881	do	285	0	73	do	S	3		
Mrs. S. Croop	6	9	13	1888	do	315	0	75	do	I	3	350	
W. H. Hurd	8	9	13	1893?	do	277	0	73	do	I	7		
Silas Bowman	5	9	13	1892	do	310	0	73	do	S	Small.		
Miller & Lux	13	9	13	Old.	do		0	74	do	S			
M. Rahilly	14	9	13	1886?	do	230	0	73	do	S	*a* 1	250	

Mrs. C. Desmarais	13	9	13	1876?	do	315	0	73	do	D, S	Small.		
Do	13	9	13	1875	do	375	0	73	do	S	a 1		
Do	23	9	13	1875?	do	300?	0	73	do	S	a 1		
J. T. Flanagan	24	9	13	1886?	do	160	0	71	do	D, S	Small.		
Do	24	9	13	1886?	Bored, 10 inches	1,000?	0	77	do	S, I	16	1,500	
Do	23	9	13	1886?	Bored	250?	0	72	do	I	Small.		
H. H. Hail	23	9	13	1893	Bored, 7 inches	297	0		do	D, S	Small.		
Do	23	9	13	1881?	do	275?	0		do	D, S	Small.		
Anna D. Ehlers	15	9	13	1887	do	300	0		do	D, S, I	Small.	300	
Do	15	9	13	1889?	do	70	8.3		Hand	D			
Do	13	9	13	1887	do	300	0	74	Artesian	D, S, I	Small.	300	
Do	15	9	13	1887	do	300	0	74	do	S	Small.	300	
James F. Chamberlain	21	9	13	1880?	do	350	0	74	Artesian	S	6	$300	
Do	29	9	13		Bored, 1½ inches	20	7	69	Hand	S			
Do	21	9	13	1880?	Bored, 9½ inches	400	0	74	Artesian	S, I	a 4		
Do	21	9	13	1875	Bored, 7 inches	350	0	74	do	S, I	a 2		
Do	28	9	13	1883?	do	360?	0	73	do	S	4		
Do	21	9	13	1880?	do	340	0	74	do	S		300	
Do	22	9	13	1883?	do	360?	0	74	do	S	a 2		
Walter Hickman	27	9	13	1905	Dug	29	10.8		Gas	I	50		
Do	26	9	13	1880?	Bored, 7 inches	300	0	73	Artesian	D, I	a 1		
California Pastural & Agricultural Co	25	9	13	Old.	do		0	73	do	S	a 2		
Do	25	9	13	Old.	Bored, 6 inches		0	72	do	S	Small.		
Do	1	10	13	1904	Bored, 7 inches	270	0		do	S	a 4		

a Yield estimated or statement of owner taken.

MADERA COUNTY.

GENERAL CONDITIONS.

The valley portion of Madera County is limited on the south and west by San Joaquin River and on the north by the Chowchilla. Irrigation by surface water is practiced about Madera through the utilization of Fresno River water in the early summer, when it is available, and about Minturn, near the north edge of the county, by the similar use of Chowchilla River water. Both of these streams have small mountain drainage basins, so that the flow from them is not prolonged late into the summer.

The extreme western edge of the county is also under irrigation from gravity water. The Chowchilla canal heads on the north side of the San Joaquin, about 6 miles east of Mendota, and runs northward, generally parallel to the river, for about 20 miles, commanding a strip 5 or 6 miles wide between it and the river. The greater part of the rest of the county is as yet grain land or pasture land, intensive cultivation being practiced only locally, extensive holdings near the river being given over to stock ranches.

FLOWING WELLS.

The ground waters have not been drawn upon to any extent for irrigation in the developments that have taken place thus far. There are about 30 flowing wells in the 350 square miles of artesian water-bearing land in the county, and these are practically all used for watering stock on the Chowchilla ranch and the Bliss and Miller & Lux properties. The total yield for all of the flowing wells is estimated to be less than 8 cubic feet per second, although at least one of the individual wells yields more than 1 cubic foot per second. These wells are generally shallow, depths of 200 to 400 feet being usual. Some of them are among the oldest in California, having been drilled nearly 40 years ago, and though there has been some lessening in yield it is doubtless due to deterioration of the casing and to clogging. A table of measurements made at different periods is appended:

TABLE 46.—*Yield of flowing wells in Madera County.*

Location.	Yield in miner's inches.		
	1871	1884	1905
Sec. 21, T. 10 S., R. 14 E	20	13	10
Sec. 4, T. 10 S., R. 15 E	22	18	11
Sec. 25, T. 10 S., R. 15 E	4	6	....
Sec. 16, T. 10 S., R. 14 E	1.1	3	12
Sec. 23, T. 10 S., R. 13 E	....	5	2
Sec. 14, T. 10 S., R. 13 E	....	23	12

The well in sec. 16, T. 10 S., R. 14 E., was recently cleaned and responded with a stronger flow than it had ever yielded before. The fact of a well-maintained pressure and supply is further indicated by the strong flows of new wells put down in the vicinity of older ones, tapping the same water-bearing beds.

It is evident that these cheap waters can be developed in large volume in the western part of Madera County if it is desired.

PUMPING PLANTS.

About 15 pumping plants in the county were in use for irrigation in 1906. Most of these are in the vicinity of Borden, where the ground-water level lies at a depth of from 10 to 20 feet. The pumps pull the water level down locally 15 or 20 feet, so that the total lift is usually 25 to 40 feet. Irrigators estimate that under these conditions they can deliver water for about 75 cents per acre-foot for fuel and labor. Even lower figures are given for the best-equipped plants.

Interest on investment and deterioration of plant, of course, increase this cost somewhat, yet it is certainly well within the limits of profitable use. Practically everywhere within that part of the county west of the Southern Pacific, except near the bluffs of San Joaquin River, pumping waters are accessible. As the foothills are approached, depth to ground water increases and the lift necessary in their development increases correspondingly.

QUALITY OF WATER.

The waters that were tested in Madera County away from the axis of the valley are similar to those in the east part of Merced County. Wells 20 to 400 feet deep yield water good for irrigation and fair to poor for boiler use. The supplies are low in alkali and moderate in scale-forming constituents, and wells probably could be bored to 1,000 feet without striking poorer water. The quality of the water from the 1,310-foot well in sec. 32, T. 11 S., R. 18 E., indicates that the very deep supplies are salty and therefore unfit for use.

Flowing wells 240 to 400 feet deep on the Chowchilla and Bliss ranches in the northwest part of the county near San Joaquin River yield supplies perfectly acceptable for irrigation, and another in sec. 34, T. 11 S., R. 16 E., probably between 300 and 500 feet deep, yields good water; artesian waters between the 300 and 500 foot depths and 9 miles or more from the river are probably satisfactory. But the water from the 520-foot well at Berendo Sheds in sec. 6, T. 13 S., R. 15 E., is strongly saline and unfit for use either in boilers or for irrigation. An artesian water from a well of nearly the same depth at Miller pumping station, 4 miles farther west (analysis, Table

51, p. 238), is higher in sulphate but much lower in chloride. A plugged 96-foot well at the latter place is said to have yielded salt water. The 437-foot well in sec. 33, T. 11 S., R. 13 E. (analysis, Table 50, p. 238), also yields salt water. These data, with those regarding artesian supplies around South Dos Palos, indicate that flowing wells near San Joaquin River are likely to strike salt water between 400 and 600 feet, and there is no good reason for believing that deeper supplies would be any better.

Tables 47 and 48 give the analyses and assays of the ground waters of Madera County that have been examined.

Owner.	Alkali coefficient (k) (inches).	Classification.			
		Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.
Geo. D. Bliss	100	Moderate	Ca-CO_3	Fair	Good.
Do	70	...do	...do	...do	Do.
Miller & Lux	70	...do	...do	...do	Do.
Do	14	...do	Na-CO_3	...do	Fair.
Do	1.2	Very high	Na-Cl	Very bad	Bad.
Sharon estate	80	Moderate	Ca-CO_3	Fair	Good.
Mrs. Casey	70	...do	...do	...do	Do.
Miller & Lux	50	...do	...do	...do	Do.
Do	50	...do	...do	...do	Do.
Sharon estate	140	...do	...do	...do	Do.
Thomas Houlding	25	...do	...do	...do	Do.
H. W. Thomas	19	...do	...do	Poor	Do.
Sharon estate	45	...do	...do	...do	Do.
Pope & Talbot	80	...do	...do	Fair	Do.
A. L. Sayre	55	...do	...do	...do	Do.
Do	1.8	High	Na-Cl	Very bad	Bad.
S. Y. Cockrum	25	Moderate	Na-CO_3	Fair	Good.
S. Shepherd	140	...do	Ca-CO_3	...do	Do.

bably more than 300 feet.

Owner.	Date	Classification.			Analyst.
		Chemical character.	Quality for boilers.	Quality for irrigation.	
Geo. D. Bliss	Oct. 19	Ca-CO_3	Fair	Good	F. M. Eaton.
Sierra Vista Vineyard Co.	...do	...do	Good	...do	Do.
Southern Pacific Co	May,	...do	Fair	...do	Southern Pacific Co.
Atchison, Topeka & Santa Fe Railway Co.	Oct. 1	Na-CO_3	...do	...do	Kennicott Water Softener Co.

[a] C., oxides of iron and aluminum.

TABLE 47.—*Field assays of ground waters in Madera County.*

[Parts per million except as otherwise designated.]

Owner.	Date, 1910.	Location. Sec.	T.	R.	Depth of well (feet).	Determined quantities. Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Computed quantities. Total solids.	Scale-forming ingredients (s).	Foaming ingredients (f).	Probability of corrosion [a] (c).	Alkali coefficient (k) (inches).	Classification. Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.
Geo. D. Bliss	Oct. 19	35	0 S.	14 E.	240	0	85	Tr.	20	76	160	130	30	N. C.	100	Moderate	$Ca\text{-}CO_3$	Fair	Good.
Do	...do...	11	10 S.	14 E.	400	0	82	Tr.	30	63	170	110	50	N. C.	70	...do	...do	...do	Do.
Miller & Lux	Oct. 23	35	12 S.	14 E.	16	0	78	15	30	86	190	140	50	?	70	...do	...do	...do	Do.
Do	Oct. 22	32	12 S.	15 E.	42	Tr.	167	5	30	69	250	120	160	N. C.	14	...do	$Na\text{-}CO_3$	...do	Fair.
Do	Oct. 23	6	13 S.	15 E.	520	0	126	287	1,680	398	3,300	430	3,200	C.	1.2	Very high	Na-Cl	Very bad	Bad.
Sharon estate	Oct. 20	11	10 S.	16 E.	46	0	83	Tr.	25	89	160	140	20	?	80	Moderate	$Ca\text{-}CO_3$	Fair	Good.
Mrs. Casey	...do...	23	10 S.	16 E.	50	0	93	Tr.	30	100	180	150	20	?	70	...do	...do	...do	Do.
Miller & Lux	...do...	33	10 S.	16 E.	44	0	109	Tr.	40	140	210	190	10	?	50	...do	...do	...do	Do.
Do	Oct. 22	34	11 S.	16 E.	([b])	0	95	Tr.	25	72	170	120	50	N. C.	50	...do	...do	...do	Do.
Sharon estate	Oct. 20	1	10 S.	17 E.	100	0	81	Tr.	15	73	140	110	20	N. C.	140	...do	...do	...do	Do.
Thomas Houlding	Oct. 22	21	11 S.	17 E.	19	0	202	5	50	148	310	200	120	N. C.	25	...do	...do	...do	Do.
H. W. Thomas	...do...	30	11 S.	17 E.	52	0	198	5	105	192	400	220	160	N. C.	19	...do	...do	Poor	Do.
Sharon estate	Oct. 20	28	9 S.	18 E.	100	6	227	5	25	186	300	240	70	N. C.	45	...do	...do	...do	Do.
Pope & Talbot	...do...	8	10 S.	18 E.	180	0	78	Tr.	25	98	160	150	0	?	80	...do	...do	Fair	Do.
A. L. Sayre	Oct. 22	31	11 S.	18 E.	100	0	87	Tr.	25	67	160	120	50	N. C.	55	...do	...do	...do	Do.
Do	Oct. 21	32	11 S.	18 E.	1,310	0	137	Tr.	1,160	776	2,000	800	1,300	C.	1.8	High	Na-Cl	Very bad	Bad.
S. Y. Cockrum	Oct. 22	5	12 S.	18 E.	60	0	149	Tr.	20	77	210	130	90	N. C.	25	Moderate	$Na\text{-}CO_3$	Fair	Good.
S. Shepherd	...do...	30	12 S.	18 E.	60	0	99	Tr.	15	86	160	140	20	N. C.	140	...do	$Ca\text{-}CO_3$	...do	Do.

[a] C., corrosive; N. C., noncorrosive; ?, corrosion uncertain or doubtful.

[b] Artesian well, depth unknown; probably more than 300 feet.

TABLE 48.—*Mineral analyses of ground waters in Madera County.*

[Parts per million except as otherwise designated.]

Owner.	Date.	Location. Sec.	T.	R.	Depth of well (feet).	Determined quantities. Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Computed quantities. Scale-forming ingredients (s).	Foaming ingredients (f).	Probability of corrosion [a] (c).	Alkali coefficient (k) (inches).	Classification. Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.	Analyst.
Geo. D. Bliss	Oct. 19, 1910	11	10 S.	14 E.	400	......	0.10	22	5.1	[b] 15	0	90	0	25	200	125	40	N. C.	80	Moderate	$Ca\text{-}CO_3$	Fair	Good	F. M. Eaton.
Sierra Vista Vineyard Co.	.....do......	13	9 S.	15 E.	170	......	.20	13	4.0	[b] 12	0	71	0	12	147	95	30	N. C.	80	Low	...do	Good	...do	Do.
Southern Pacific Co	May, 1900	19	10 S.	17 E.	90	[c] 74	......	21	11	21	0	85	24	33	226	155	60	?	60	Moderate	...do	Fair	...do	Southern Pacific Co.
Atchison, Topeka & Santa Fe Railway Co.	Oct. 1, 1902	17	11 S.	18 E.	......	[c] 63	......	16	3	27	0	81	5	27	181	115	70	N. C.	40	...do	$Na\text{-}CO_3$	...do	...do	Kennicott Water Softener Co.

[a] C., corrosive; N. C., noncorrosive; ?, corrosion uncertain or doubtful.

[b] Computed.

[c] Including oxides of iron and aluminum.

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WELL RECORDS.

The essential facts secured as to the most important wells in Madera County examined by Messrs. A. J. Fiske, jr., R. M. Priest, and S. M. Smith in 1905–6 have been assembled in the accompanying table.

TABLE 49.—*Records of wells in Madera County.*

Owner.	Location. Section.	Township south.	Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.[a]	Quantity of water.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
W. D. Cardwell	28	9	16		Bored, 7 inches	54	22	66	Horse	D, S			
Sharon estate	30	9	17		Bored, 8 inches	72	48		do	N			
Do	28	9	17		do	100	65	67	Wind	N			
Do	23	9	17		do	85	57		Horse	S			
Do	19	9	18		do	100	50		Wind	N			
J. F. Daulton	20	9	18		do	60	30	60	Horse	D, S			
Sharon estate	28	9	18		do	100	72		do	N			
J. F. Daulton	29	9	18		do	26	26	68	Wind	D, S			
Pope & Talbot	8	10	18		do	+125	+100	65	do	D, S			
Sharon estate	1	10	17		do	100	50		Horse	N			
Do	11	10	11		do	75	46		Wind	N			
Do	5	10	17		do	110	50	67	do	S			
H. H. Stark	8	10	17		do	60	37	67	do	D, S			
McCabe Bros	2	10	16		Bored, 6 inches	40	22	66	do	D, S			
Sharon estate	11	10	16		Bored, 8 inches	46	21		Horse	N			
Do	10	10	16		Bored, 7 inches	52	21	65	Wind	S			
Do	15	10	16		do	47	20		Horse	D, S			
Mr. Hemmel	9	10	16		Bored, 6 inches	65	22		do	D, S			
C. H. Brown	5	10	16	1890	do	40	23	67	Wind	D, S			
O. W. Garlinghouse	33	9	16		Bored, 8 inches	48	24		do	D, S			
California Pastural & Agricultural Co	4	10	15		Bored, 7 inches		0	72	Artesian	S	4		
Do	5	10	15	1887	do	212	0	70	do	S	[b] 3		
Do	8	10	15		do		0		do	S			
Do	16	10	15		Bored, 8 inches		0	70	do	S	Small		
Do	4	10	14	1875?	Bored, 7 inches		0		do	S			
Do	5	10	14	1899	Bored, 10 inches	324	0	72	do	S	5		
Do	6	10	16		Bored, 7 inches	210	0		do	S			
Do	14	10	13		do	297	0	73	do	S	12		
Do	23	19	13		do		0	73	do	S	[b] 2		
Do	17	10	14	1905	do	264	0	72	do	S	[b] 4		
Do	16	10	14	1869	Bored, 8 inches	240	0	71	do	S	12		
Do	29	10	14	1899	Bored, 7 inches	305	0	73	do	S	58		

[a] D, domestic; S, stock; I, irrigation; B, boilers; N, not used.

[b] Yield estimated or statement of owner taken.

TABLE 49.—*Records of wells in Madera County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Quantity of water.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
California Pastural & Agricultural Co.	24	10	14		Bored, 6 inches	173	0	72	Artesian	S			
Do	28	10	15		Bored, 7 inches		0	73	do	S	*a* 3		
Do	21	10	15		Bored, 6 inches	200	0	73	do	S	*a* 10		
Do	25	10	15		Bored, 7 inches	175	0		do	S			
Do	6	11	16		do	175	0		do	S			
Miller & Lux	13	11	15		Bored, 8 inches	+200	0	75	do	S			
California Pastural & Agricultural Co.	4	11	15		do	235	0	72	do	S	11		
Do	4	11	15		Bored, 7 inches	244	0	71	do	S	20		
Do	6	11	15	1899	Bored, 10 inches	262	0		do	S	12		
Do	20	11	15	1899	do	225	0		do	S	7		
Do	9	11	14		Bored, 7 inches	314	0	72	do	S			
Do	21	11	14		do	297	0	72	do	S			
Do	32	11	15	1904	do	336	0		do	S	26		
Miller & Lux	35	12	14		do	16	10		Hand	D, S			
Do	6	13	15	1892	do	520	0		Artesian	S			
Do	32	12	15	1877	do	*b* 42	10		Hand, wind				
Do	17	13	15	1887	do	30	10		Hand	D			
Do	14	13	15	1903	Dug, 4 by 5 feet	10	8		do	D, S			
Do	19	12	16	1897	Bored, 7 inches	45	15		Wind, horse	S			
Do	23	12	16	1897	do	*b* 60	15		Hand, horse	S			
Do	17	11	16		Bored, 8 inches	+200	0	74	Artesian	S			
Do	8	11	16		do	+200	0	73	do	S			
Do	21	11	16		do	+200	0		do	S			
Do	34	11	16		Bored, 6 inches		0	74	do	S	Small		
Do	34	11	16		Bored, 4 inches		0	75	do	S	do		
Do	33	10	16		Bored, 6 inches	44	17	66	Wind	S			
Do	2	11	16	1885	Bored, 4 inches	42	14	66	do	D, S			
Do	14	11	16	1890	Bored, 6 inches	30	12	68	do	D, S		$25	
J. Joyce	35	10	16		Bored, 6 inches	45	20	67	do	D, S			
F. F. Moran	25	10	16	1887	do	52	24	68	do	D, S			
Mrs. Cassey	23	10	16		do	50	25	67	do	D, S			
Olcese & Buckeran	24	10	16		do	44	25		Horse	N			
J. G. Anner	18	10	17	1890	Bored, 7 inches	58	31	67	Wind	D, S			
H. D. Crow	30	10	17		Bored, 6 inches	62	22	67	do	D, S		30	
Miller & Lux	34	10	17	1887	Bored, 8 inches		21	70	do	D, S			
Do	27	10	17		do		22		Horse	S			
Do	22	10	17	1890	Bored, 6 inches	86			Wind	D, S			
Do	23	10	17		Bored, 7 inches	80	48	67	Horse	D, S			
Do	26	10	17		Bored, 8 inches	125	62	67	Wind	D, S			
Pope & Talbot	20	10	18		do	98	82		do	D, S			

Do	8	10	18	1895	do	180	+100	68	do	D, S			
Archible estate	14	10	18		do	+100	95		do	D, S			
Do	22	10	18		do	+110	110	69	do	D, S			
Pope & Talbot	29	10	18		do	125	85	67	do	D, S			
Miller & Lux	36	10	18		Bored, 7 inches	+ 75	75	72	Horse	D, S			
Hatch & Service	1	11	18		Bored	175	+75	68	Wind	D, S			
Madera County	32	10	19		Bored, 8 inches	45	41	68	Hand	D, S			
Miller & Lux	33	10	19		do		63	69	Wind	S			
G. D. Woolten	36	10	19	1905	Dug	28	12		Horse			149	
Bates post office	29	10	20		Bored, 6 inches	23	8	66	Wind	D, S			
G. D. Woolten	3	11	19		Bored, 8 inches	185	150	70	Horse	D, S		375	
J. R. White	19	10	20	1885	Dug	40	35	66	Wind	D, S			
Mr. Lankenshire	5	11	18	1904	Bored, 8 inches	90	40	70	do	D, S			
Miller & Lux	1	11	17	1892	do	55	32		Horse	D, S			
Do	11	11	17	1890	Bored, 6 inches		45		do	S			
Do	2	11	17		Bored, 10 inches		24		do	S			
Chas. Schmidt	11	11	17	1898	Bored, 8 inches	87		67	Wind	D, S			
H. Hall	9	11	17		do	50	17	66	do	D, S			
Miller & Lux	4	11	17		Bored, 4 inches	38	16		Horse	D, S			
Do	7	11	17		Bored, 6 inches	25	12	66	Wind	D, S			
Do	17	11	17		do	32	13	65	do	D, S			
Madera Water Co	24	11	17	1896	Bored, 8 inches	630	18		Steam	D	50		
Do	24	11	17	1896	do	230							
Do	24	11	17	1896	do	110							
Do	24	11	17	1896	do	320							
Madera Canal Co	8	11	18	1896	Bored, 7 inches	85	16	72	Hand	D, S			
Santa Fe Ry. Co	16	11	18	1896	do	175	100?		Steam	D, B	a 10		
Lankershim estate	16	11	18	1904	Bored, 6 inches	34	15		Wind	D, S		50	
M. L. Alley	17	11	18		Dug, 5 feet	22	12	70	do	D			
A. N. Campbell-Johnston	30	11	18	1905	Bored, 8 inches	54	7	70	do	D		50	
A. L. Sayre	32	11	18	1884	Bored, 7 inches	1,310	0	72	Not raised	N		3,400	
A. L. Sayre c	31	11	18	1903	Bored, 12 to 10 inches.	110	16	72	Gas	I	a 317		
Sacramento Bank	25	11	17	1889	Bored	50	11?	68	Hand	D, S			
Mrs. C. I. Miller	25	11	17	1895	Bored, 5 inches	90	9?		Wind	D, S		50	$60
H. Giles	25	11	17	1889	Bored, 4 inches	62	15?	70	do	D, S		30	30
F. E. Briscol	36	11	17	1904	Bored, 5 inches		7		do	D, S			75
W. G. Woodson	26	11	17	1875	Bored, 7 inches	78	6		Hand	D, S		65	4
Midvale Land & Fruit Co	23	11	17		do	45	9?	70	Wind	D, S		40	60
Mr. Harris	23	11	17	1904	Bored, 10 to 9 inches.	140	9.5?	70	Gas	I	a 222	400	2,000
Do	23	11	17	1904	do	180	9.5		do	D, S			
Do	23	11	17	1904	do	185	9.5		do	D, S			
A. L. Dorsam	22	11	17	1900	Bored, 7 inches	125	18?	70	Wind	D, S		58	100
R. B. Stockton	22	11	17	1893	Bored, 6 inches	33	9		do	D, S		33	60
H. H. Hawley	22	11	17	1893	Bored, 7 inches	26	7	68	do	D, S		20	45
Stephen Clark	22	11	17	1891	do	30	11		do	D, S		25	50
L. D. Williams	27	11	17	1902	Bored, 5 inches	35	8.5		do	D, S		17	75
Thomas Houlding	21	11	17	1892	do	19	5.5		do	D, S		10	35
Paolo Delavale	21	11	17		do	18	6	67	Hand	D, S		9	4
Cesare Del Bono	28	11	17	1902	Bored, 7 inches	20	8	69	Wind	D, S		28	35

a Yield estimated or statement of owner taken. b Two wells. c Three wells.

TABLE 49.—*Records of wells in Madera County*—Continued.

Owner.	Location. Section.	Township south.	Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Quantity of watea.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
Joseph H. Noble	29	11	17	1903	Bored, 7 inches	25	8?		Wind	D, S		$20	$75
H. W. Thomas	30	11	17	1894	2 inches	52	9?		do	D, S		50	40
Do	30	11	17		Bored, 5 inches	47	11		Not raised	N		25	
G. L. Hardwell	30	11	17		Bored, 7 inches	20	11	68	Wind	D, S		18	50
Pope & Talbot	12	12	16		Bored, 10 inches	130	10?		Gas	I	*a* 89		
L. & S. Sledge	32	11	17	1885	Bored, 7 inches	60	9	73	Wind	S			
Borden Farm Co	33	11	17		do	26	6		do	D, S		25	75
Italian Swiss Colony	34	11	17		Bored, 6 inches	75	11?		Steam	I	7		
C. W. Rouch	27	11	17	1901	Bored, 7 inches	34	8.5	70	Wind	D, S		40	45
Dorn Vineyard	27	11	17		do	+100	8	70	do	D, S			75
Teresa Mumphrati	35	11	17		Bored, 6 inches	56	10		do	D, S		40	65
R. S. Vogeler	35	11	17	1897	do	115	23?	70	do	D, S		80	100
S. J. Perkins	35	11	17	1897	Bored, 7 inches	45	16?		do	D, S		40	125
Henry Shadle	35	11	17	1902	do	40	9	68	do	D, S		41	72
Alpha school district	2	12	17		do	42	7		do	D		35	75
T. B. Wren	2	12	17	1902	do	+50	7	37	do	D, S		70	50
German Savings Bank	2	12	17	1902	Bored, 5 inches	70	20?	70	Hand	D, S			4
A. N. Campbell-Johnston	12	12	17		Bored, 7 inches		7.5		Wind	D, S			65
J. Bixby	1	12	17	1892	do	25	15?		do	D, S		20	60
Borden & Freeland	7	12	18		Bored, 8 inches	60	11		do	D, S			
J. Cunningham	6	12	18	1883	Bored, 7 inches	100	9?		do	D, S		125	100
Brown Bros	5	12	18	1905	do	114	16	68	Gas	I, D	8		188
S. Y. Cockrum	5	12	18	1904	Bored, 10 inches	105	26		do				
Do	5	12	18	1904	do	168	26		do	I	*a* 222		*b* 3,500
Walters Bros	32	11	18	1903	Bored, 10 inches	174	11		} do	I			
Do	32	11	18	1903	do	104	11						
Lankershim estate	33	11	18		Bored, 7 inches	80	27		Wind	D			
J. C. Secara [c]	4	12	18		do	76	26		do	D, S			
T. O. Cavin	4	12	18	1890?	do		34?		do	D, S			
Geo. Hollister	3	12	18		do	57	28		do	D, S			
Mathew Bros	3	12	18	1901	Bored, 10 inches	98	28		} Steam	I			*b* 2,000
Do	3	12	18	1901	do	160	28						
H. G. Macon	3	12	18	1875	Bored, 7 inches	80	35		Wind	D, S			
Miller & Lux	25	11	18	1898	do	100	50?		do	D, S			
San Francisco Savings Union	1	12	18	1904	do	104	46	73	do	D, S		90	140
Madera Farmers Warehouse	1	12	18	1900	Bored, 6 inches	80	44		Hand	D, S			
A. E. Jones	1	12	18		Bored, 7 inches		44		Wind and gas	D, S, I			180
D. B. Lavelle	11	12	18	1885	do		52?		Wind	D, S			
W. B. Garner	7	12	19	1902	do	101	68		do	D, S			

J. E. Stevens	33	11	19		do	275	80		do	D, S			
Miller & Lux	35	11	19	1903	do	140	96		Horse	D, S			
Wm. Healey	2	12	19	1885	do	95	82?	74	Wind	D, S			
J. F. Lewis	1	12	19	1888	Bored, 7 inches	125	100?		do	D, S			
P. O. Cavin	31	11	20	1904	do	100	75?		do	D, S			
Clapp & Butin	32	11	20	1904	do	200	80		do	D, S			
Mrs. Stevens	16	12	20		do	125	100?		do	D, S			
Cobb & Littler	17	12	20	1893	do		100?		do	D, S			
A. C. Coulthard	13	12	19	1887	do	122	96		do	D, S			
W. F. Hamilton	13	12	19	1896	do	106	100?		do	D, S			
W. T. Pitman	14	12	19	1904	do				do	D, S			
John Radley	15	12	19	1890?	do	100	83?		do	D, S			
Santa Fe Ry. Co	18	12	19		Bored, 6 inches	80	64?	72	do	D, S			
Georges Hely	9	12	18	1870	Bored, 7 inches	65	20		do	D, S			
Do	8	12	18	1904	do	123	18		Gas	I	a222		b3,000
Do	8	12	18	1904	Bored, 16 inches	85	18						
M. L. Borden	8	12	18	1903	Bored, 10 inches	105	22		Steam	I			b2,000
Borden & Freeland d	7	12	18	1899	do	120	16		do	I	a111		b5,000
H. W. Paterson	8	12	18	1903	do	134	22		do	I			
Do	8	12	18	1903	do	96	22						
Do	8	12	18	1903	Bored, 7 inches	90?	20?		Wind	D			
G. W. Mordecai	7	12	18	1880	do	50	16?		do	S			
Margaret and May Minor	11	12	17	1904	do	60	14?	72	do	D, S		60	60
J. L. Butin	10	12	17	1904	Bored, 8 inches	152	5?		Gas	I		350	1,400
Do	10	12	17	1904	do	147	5?						
J. S. Osborn	10	12	17	1883	Bored, 7 inches	40	12?		do	D, S		40	175
John Conley	10	12	17	1904	do	53	6		Wind	D, S		45	50
A. Wiehe	9	12	17		do		6.5	70	do	S			50
Louisa Pinasco	9	12	17	1899	do	75	7		Horse	I		65	300
A. E. Waters	9	12	17	1897	do	+100	6		Wind	D, S		126	60
J. P. Gallener	9	12	17	1893	Bored, 8 inches	56	7	70	do	D, S		55	35
Italian Swiss Colony	17	12	17		Bored, 7 inches		9	70	do	D, S			75
Yosemite Stage & Turnpike Co	16	12	17	1888?	do	35	7?		do	D, S		30	75
T. L. Noble	15	12	17	1903	do	50	5?	68	do	D, S		40	60
Sam Rowe	22	12	17		do	42	12?	70	Hand	D, S		35	4
German Savings & Loan Society	26	12	17		do		13		Wind	D, S			60
P. C. Easton	25	12	17		do		20?		do	D, S			60
G. E. & A. K. Ripperdan	36	12	17	1887	Bored, 8 inches	70	32?		do	D, S		70	40
E. McGarvin	19	12	18	1905	Bored, 12 inches	50	32?		Steam	I	a70		b1,250
Do	19	12	18		Bored, 7 inches	80	30?		Wind	D, S			
S. Shephard	30	12	18	1885	do	60	28		do	D			
E. G. Hope	29	12	18	1875	Bored, 8 inches	68	28		do	D, S		68	175
Do	28	12	18	1880	do	82	26		do	D, S		82	154
J. H. Shedd e	28	12	18	1875	Bored, 7 inches	100	42		do	D, S		200	
A. Lusk	34	12	18		Bored, 8 inches		45		do	D, S			
J. L. Price	33	12	18		do	80	40?		do	D, S			
A. A. Skaggs e	31	12	18	1874–5	do	75	37		do	D, S			
Miller & Lux	1	13	17	1900	Bored, 7 inches	100	30?		Horse	D, S		85	
Do	2	13	17	1893	Bored, 10 inches	125	35	72	Wind	D, S		150	60
Do	5	13	17	1893	do	100	30	72	do	D, S		100	60

a Yield estimated or statement of owner taken. b Cost of well and equipment combined. c Three wells. d Four wells. e Two wells.

FRESNO COUNTY.

GENERAL CONDITIONS.

The part of Fresno County within San Joaquin Valley contains one of the largest and most intensively cultivated areas as well as a portion of the most barren territory in the Great Central Valley. The rainfall, which gradually decreases in amount from the mouth of the Sacramento southward, is so slight in Fresno County that dry farming is precarious, hence most of the unirrigated land is also uncultivated and is used only as range. Around Fresno and south and east of that city luxuriant crops of great diversity are grown; raisin, table, and wine grapes, peaches, almonds, apricots, and other high-priced products are chiefly cultivated, while hay and cereals yield good returns in the less thickly settled portions of Kings River delta.

This rich and populous region is irrigated by gravity water, distributed by a network of canals that take their supply from the river. These irrigation systems have been fully described by Grunsky.[1]

A later paper, by Lippincott,[2] dealing with the possibility of storage and the development of water power on Kings River, embodies the results of a close study of the ground waters and their relation to alkali conditions by Louis Mesmer and Thomas H. Means. From this report (pp. 53, 54, and 85) the following quotations are taken:

The natural drainage of these lands is toward the southwest, at the rate of about 6 feet to the mile. The soil is largely granitic sand, and below an average depth of 10 or 15 feet it is saturated with water. The surface water is somewhat alkaline, and therefore it is not advisable to pump it for irrigation. Water below a depth of 50 feet can be considered satisfactory for irrigation. This is based on tests of more than 800 wells in the district, some of them being in sections where there were the strongest surface alkaline indications. In every case this lower water was found to be good, and when the strata near the surface are penetrated it rises to the elevation stated. There have been few attempts to pump water in larger quantity than is required for domestic purposes. A 2-inch screw pipe, put down to an average depth of 50 feet, landing the pipe on a stratum of clay, and then boring through the clay and allowing the water to come in from the bottom of the hole, is always ample for this purpose.

* * * * * * *

A few small pumping plants have been installed—one 5 miles east of Fresno, on Minnewawa ranch; several around Selma, and two near Wildflower—which yield at least 0.5 second-foot to a 7-inch unperforated well not more than 70 feet deep, with a lift not to exceed 20 feet in any case. Wells of 10-inch or 12-inch casing should be put down to a depth of about 100 feet on an average, and should not be perforated above 50 feet below the surface, thus shutting off all possible chance of drawing from the more or less alkaline surface water. It is probable that wells of this size and depth would each furnish 1.5 second-feet.

* * * * * * *

The result of pumping * * * would be to improve the conditions rather than to increase the trouble from alkali. The water table would be lowered sufficiently to permit the washing down of the alkali salts, and the salts, instead of being confined to the surface layers of the soil, would gradually be distributed * * * and by this

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[1] U. S. Geol. Survey Water-Supply Paper 18, pp. 39 et seq., 1898. Out of print. May be consulted in libraries.

[2] U. S. Geol. Survey Water-Supply Paper 58, 1902. Out of print. May be consulted in libraries.

dilution rendered harmless. The lowering of the water table would be of the greatest assistance to the reclamation of the lands already alkaline, and would probably permit this reclamation without extensive underdrains.

Other reports dealing with the problem of alkali and drainage have been prepared by Fortier, Mackie, and Cone.[1] In a report by Lewis A. Hicks on the "Generation and transmission of electric power and installation of pumping plants," included in Water-Supply Paper No. 58, an estimate has been made of the cost of water pumped from the ground-water supply by electric power generated on Kings River. The estimates are made on the basis of 100 pumping stations, each with a maximum capacity of 5 second-feet and an average lift of 45 feet, and the probable cost of the water produced is given as 50 cents per acre-foot when the pumping plants operate 328½ days per year and $1.43 when the pumping plants operate 100 days per year.

Among the conclusions reached by Mr. Lippincott[2] after a thorough investigation of conditions on the Kings River delta are the following

Pumping plants can be established and operated which will furnish 1,000 acre-feet of water per day at a cost not much greater than that now paid for gravity water from the canals, to supplement the present summer supply or to extend the irrigated areas.

The operation of the pumping plants will partially if not wholly prevent the rising of alkali to the surface of irrigated lands.

The rise of the ground waters presents a difficult problem in practically all of the delta lands of the San Joaquin Valley, and is merely particularly well exemplified in the Kings River delta in Fresno County. Mr. Grunsky states that the rise in ground waters since the beginning of irrigation is from 10 to as much as 50 feet in parts of the delta. One great difficulty that arises in dealing with the problem is due to the fact that the injury is done in one locality while a large part of the cause may be in another. The lower delta lands are the chief sufferers from the rise of the ground waters, but the cause is to be found in the irrigation on the higher lands as well as on those affected. Over portions of the central artesian basin and about its borders the ground waters have always stood close to the surface, and much of the land was impregnated with alkali before there was any settlement in the valley. The effect of the irrigation on the higher lands has been to extend this saturated alkali zone slowly up the slope toward the eastern margin of the valley until it has encroached to a certain extent upon lands that were valuable.

Without storage the gravity waters will not serve an acreage greatly in excess of that supplied by them now, and the pumping

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[1] Mackie, W. W., Reclamation of white-ash lands affected with alkali at Fresno, Cal.: U. S. Dept. Agr. Bur. Soils Bull. 42, 1907.

Fortier, Samuel, and Cone, V. M., Drainage of irrigated lands in the San Joaquin Valley, Cal.: U. S. Dept. Agr. Off. Exper. Sta. Bull. 217, 1909.

Cone, V. M., Irrigation in the San Joaquin Valley, Cal.: U. S. Dept. Agr. Office Exper. Sta. Bull. 239, 1911.

[2] Lippincott, J. B., Storage of water on Kings River, California: U. S. Geol. Survey Water-Supply Paper 58, p. 98, 1902.

plants that must be installed to secure future growth will in addition serve a most valuable function in drainage, tending to prevent the extension of alkali conditions and aiding in the reclamation of lands already containing too much alkali.

FLOWING WELLS.

The flowing wells of the artesian belt of Fresno County are sparsely scattered over a broad area along the trough of the valley. In 1906 there were only about 40 of them, ranging in depth from less than 100 to 1,500 feet, the latter being the depth of one of the wells belonging to the Johns estate, north of Summit Lake. In the district adjacent to Lemoore, south of Kings River, small flows, sufficient for stock and domestic use, are obtained at 150 feet and less, but farther north no shallow wells are found.

Those on the James and Herminghause ranches, south of San Joaquin River, are 600 to 800 feet deep. The flowing wells of the larger ranches were bored generally to obtain a supply of water for stock at times when none is available in the sloughs and irrigating ditches. Irrigation in these large holdings is as yet accomplished only during the flood season when abundant gravity water is available for lavish use. The possibility of using ground waters for such purposes is scarcely considered, although on one of the James ranches the water from a flowing well is used to irrigate about 50 acres of alfalfa.

The great west-side plains, with their productive soil, freedom from hardpan, good drainage, and favorable situation, are nonproductive because of their aridity, and must remain so until water can be applied to them. The ground-water plane seems to be nearly horizontal, such evidence as is at hand indicating a slope of only about 2 to 5 feet per mile; hence it is nearly as far to ground water beneath any part of these plains as the plains themselves are above the lowest part of the valley. If experiments should prove that these lands will successfully produce citrus fruits or other high-priced products, then it may be that the water can be pumped to them from the valley and the venture made commercially practicable despite the great expense involved, for it is to be remembered that water is pumped to heights of several hundred feet in Tulare and San Bernardino counties in localities where it can be used on good citrus lands with an excellent margin of profit.

At present the west slope is almost devoid of permanent residents. There are perhaps a dozen settlers between Panoche Creek and the Coalinga branch of the Southern Pacific. Sheep camps, occupied temporarily in winter, are scattered over them. In the early nineties a few seasons of heavy rainfall led to settlement about Huron, and two or three crops of grain were harvested, but since then there has usually not been sufficient rainfall to mature a crop, and the plains

have been abandoned to the sheep men, who lease the grazing privileges from the large landholders, notably the Southern Pacific Co.

QUALITY OF THE WATER.

The water from wells 20 to 200 feet deep that were tested on the east side of the county would be considered entirely suitable for use in irrigation except that within about 10 miles of Kings River Slough. In general, calcium carbonate waters of moderate mineral content are encountered on the east side, but the characteristic alkali alteration takes place toward the axis of the valley, and the upper waters are less desirable, though not absolutely harmful. According to the tests wells 100 to 300 feet deep at Fresno yield supplies containing but from 120 to 300 parts per million of mineral matter. The shallow wells yield somewhat harder water, and it is reported that the water at 600 feet is good, while a 500-foot well 6 miles northeast yields water like that of the 100 to 300 foot wells in the city. Doubtless wells could be sunk to 1,000 feet without danger in the deltas east of a line joining Jamesan and Caruthers, if it were necessary or desirable to go so deep as that for sufficient supply. Determinations by means of the electrolytic cell of the total solids in 854 ground waters in Kings River delta, including parts of Kings and Tulare counties, as well as the greater portion of the east side of Fresno County, are published in Water-Supply Paper 58.[1] Most of the wells from which the samples were taken are less than 100 feet deep, none in Fresno County being more than 300 feet deep. According to these estimates the shallow waters are moderately low in mineral content; total solids exceed 300 parts per million in only 5 per cent of the samples, and only two among several hundred samples tested in Fresno County contain more than 600 parts per million of dissolved matter.

The quality of east-side waters deeper than 1,200 feet is unknown for no wells approaching that depth could be tested. As far south as Fresno County wells more than 1,200 feet deep strike salt water, but south of that county wells as deep as 2,000 feet yield fresh water, and it is therefore evident that the final disappearance southward of excessive chlorides in the deep supplies takes place somewhere between Madera and Corcoran and probably within Fresno County. Some of the wells 550 to 800 feet deep near Jamesan Colony give brackish water, but this is no indication of the possibilities farther east, for water from moderately deep flowing wells elsewhere in the valley is better in proportion to the distance of the wells east of the axis. The water of the 1,200-foot well in sec. 2, T. 17 S., R. 18 E., contains only 135 parts per million of chlorine and 610 parts of total solids; the 2,250-foot well in sec. 14, T. 18 S., R. 18 E., contains 279 parts of chlorine and 872 parts of solids; that is, neither

[1] Lippincott, J. B., Storage of water on Kings River, California: U. S. Geol. Survey Water-Supply Paper 58, 1902.

water, though both are near the axis, where the alkali content of the waters should be greatest, approaches in saltness or in mineral content the very deep waters farther north.

The west side of the county is mostly semiarid sheep range, but the possibility of producing good crops by the use of ground water along the lower eastern edge of this west-side plain is being demonstrated around Mendota and Huron, and on several isolated farms between these settlements. Barley, Egyptian corn, alfalfa, and general garden truck are being irrigated by pumping in T. 14 S., R. 14 E.; T. 15 S., R. 14 E.; T. 15 S., R. 15 E.; and T. 20 S., R. 17 E. The ground water out on the plains is highly gypsiferous, more than 60 per cent of the total residue consisting of calcium, magnesium, and sulphate. Such water is very bad for boiler use because treatment to remove the scale-forming constituents and to neutralize the corrosive tendencies increases the foaming ingredients to so great amount that excessive foaming is likely to occur. The content of alkali is not excessive, however, and does not destroy, though it reduces, the value of the water for irrigation. The area in which such ground supplies are typical extends from South Dos Palos to the Kings-Fresno county line between the artesian belt on the east and the foothills of the Coast Range on the west. Only one well in it more than 250 feet deep was tested, and that well, 1,200 feet deep in sec.11, T. 20 S., R. 17 E., is said to be unproductive below 400 feet; it is probable that any waters that may be encountered below 250 feet are similar to those above that depth in their essential characteristics.

Plate III (p. 102) and figure 3 (p. 107) show the relation between the location and depth of wells in the artesian area and the sulphate content of their waters. Alkali bases are predominant in all of them, but otherwise they differ greatly from one another in composition and concentration. Sodium sulphate waters of high total solids are characteristic west of the slough and sodium chloride and sodium carbonate waters east of it within the limits of the artesian area. They are fair to very poor for irrigation, and supplies from shallower, nonflowing wells are superior for general use. The water of the 2,250-foot well in sec. 14, T. 18 S., R. 18 E., comes from one of the deepest borings in the valley. The analysis by Eaton shows it to be much less strongly mineralized than other supplies west of the slough, but very poor for irrigation because of its high content of bicarbonate, chloride, and alkalies; it is understood that the water killed crops to which it was applied. Its content of foaming constituents is great enough to make it undesirable for boiler use. The fact that it contains practically no sulphate, though all the other waters in the immediate vicinity are high in that constituent, indicates that the well passes through the typical west-side sediments and draws its supply from beneath them. Greater quantities of gas than are present in the other artesian waters of the county escape from the casing.

a C., corr c Two wells 45 and 75 feet deep.

Owner.	Dat	l t.	Classification. Chemical character.	Quality for boilers.	Quality for irrigation.	Analyst.
Pacific Coast Oil Co.			Na-SO_4	Very bad	Fair	Pacific Coast Oil Co.
J. G. James Co	Nov. 1		Na-Cl	do	do	F. M. Eaton.
F. C. Stillman	Nov.		Ca-SO_4	do	do	Do.
Joseph Mouren	Nov. 11		do	do	do	Walton Van Winkle.
Sanford & Claverias	do.	gh.	do	do	do	F. M. Eaton.
Southern Pacific Co	Oct. 1	e.	Na-CO_3	Fair	Good	Southern Pacific Co.
Manuel Nunez	Nov. 1		Na-Cl	Very bad	Poor	F. M. Eaton.
Pacific Coast Oil Co			Na-SO_4	do	Fair	Pacific Coast Oil Co.
Southern Pacific Co	June —	e.	Ca-CO_3	Fair	Good	Southern Pacific Co.
Do	July 8		do	do	do	Do.
Do	June 2		do	do	do	Do.
Santa Fe Ry. Co	Oct. 1		do	do	do	Kennicott Water Softener Co.
Fresno Brewing Co	Nov. 8		do	Good	do	F.M. Eaton.
Do	do.		do	Fair	do	Walton Van Winkle.
Southern Pacific Co	June 1		Na-CO_3	Good	Fair	Southern Pacific Co.
Miller & Lux	Oct. 2		do	do	Good	Do.
Pacific Coast Oil Co	Oct. 3		Na-SO_4	Very bad	Fair	Do.
M. F. Tarpey	Nov.	e.	Ca-CO_3	Fair	Good	F. M. Eaton.
Southern Pacific Co	Dec. 3		Na-CO_3	Good	do	Southern Pacific Co.
A. R. Gilstrap	Nov. 1		Ca-CO_3	Fair	do	F. M. Eaton.
Southern Pacific Co	Apr.		do	do	do	Southern Pacific Co.
Santa Fe Ry. Co	Oct.		do	do	do	Kennicott Water Softener Co.

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natter, 11 parts.

TABLE 50.—*Field assays of ground waters in Fresno County.*

[Parts per million except as otherwise designated.]

Owner.	Date, 1910.	Location. Sec.	Location. T.	Location. R.	Depth of well (feet).	Determined quantities. Carbonate radicle (CO_3).	Determined quantities. Bicarbonate radicle (HCO_3).	Determined quantities. Sulphate radicle (SO_4).	Determined quantities. Chlorine (Cl).	Determined quantities. Total hardness as $CaCO_3$.	Computed quantities. Total solids.	Computed quantities. Scale-forming ingredients (s).	Computed quantities. Foaming ingredients (f).	Computed quantities. Probability of corrosion[a] (c).	Computed quantities. Alkali coefficient (k) (inches).	Classification. Mineral content.	Classification. Chemical character.	Classification. Quality for boilers.	Classification. Quality for irrigation.
G. E. Hyslinger	Nov. 1	24	14 S.	14 E.	(b)	3	194	800	150	557	1,600	590	900	?	9	High	$Na-SO_4$	Very bad	Fair.
John Tuft	Dec. 19	9	15 S.	14 E.	238	0	130	1,400	100	1,200	2,400	1,230	690	C.	13	Very high	$Ca-SO_4$	do	Do.
Southern Pacific Co	Nov. 1	31	13 S.	15 E.	640	Tr.	147	430	75	83	910	110	800	N. C.	8	High	$Na-SO_4$	do	Do.
J. G. James Co	Dec. 8	10	14 S.	16 E.	550	0	160	273	245	38	970	90	970	N. C.	4	do	Na-Cl	do	Poor.
Southern Pacific Co	Nov. 1	14	14 S.	16 E.	200	6	122	Tr.	30	92	210	140	80	N. C.	30	Moderate	$Ca-CO_3$	Fair	Good.
W. J. Williams	Dec. 8	15	14 S.	16 E.	48	Tr.	122	5	60	16	260	70	230	N. C.	10	do	$Na-CO_3$	do	Fair.
R. B. Thompson	Dec. 10	5	15 S.	16 E.	20	0	526	363	130	445	1,200	480	740	N. C.	11	High	do	Very bad	Do.
J. G. James Co	Dec. 9	12	15 S.	16 E.	700	0	144	234	65	50	600	80	540	N. C.	18	do	$Na-SO_4$	do	Do.
Do	Dec. 8	19	15 S.	16 E.	700	0	147	480	55	167	960	200	720	?	16	do	do	do	Do.
F. C. Stillman	Nov. 7	5	17 S.	16 E.	160	0	178	828	125	854	1,600	880	440	C.	14	do	$Ca-SO_4$	do	Do.
D. I. Englund	Oct. 22	12	13 S.	17 E.	63	0	203	5	25	150	270	200	80	N. C.	35	Moderate	$Ca-CO_3$	Fair	Good.
A. J. Tuttle	Nov. 1	9	14 S.	17 E.	60	0	130	Tr.	10	21	180	70	130	N. C.	14	do	$Na-CO_3$	Good	Fair.
J. G. James Co	Dec. 9	9	15 S.	17 E.	800	0	329	65	265	40	810	90	910	N. C.	3	High	Na-Cl	Fair	Poor.
Do	do	25	15 S.	17 E.	750	Tr.	320	5	155	32	560	60	600	N. C.	4	do	$Na-CO_3$	Very bad	Do.
Do	do	33	15 S.	17 E.	15	0	375	10	15	240	410	270	140	N. C.	16	Moderate	$Ca-CO_3$	Poor	Fair.
Hellum & Co	Nov. 7	14	16 S.	17 E.	80	Tr.	254	62	45	121	410	150	300	N. C.	10	do	$Na-CO_3$	Bad	Do.
Do	do	14	16 S.	17 E.	690	6	180	154	150	40	670	70	660	N. C.	5	High	Na-Cl	Very bad	Poor.
S. B. Williams	do	22	16 S.	17 E.	70	0	437	685	10	367	1,400	400	970	N. C.	17	do	$Na-SO_4$	do	Fair.
New Hope school district	do	27	16 S.	17 E.	60	0	268	200	10	302	570	330	190	?	70	do	$Ca-CO_3$	Poor	Good.
Pacific Coast Oil Co	do	8	17 S.	17 E.	1,100	0	130	242	35	125	560	160	350	N. C.	28	do	$Na-SO_4$	Bad	Do.
Joseph Taix	Nov. 10	12	18 S.	17 E.	114	3	117	1,380	135	1,100	2,400	1,130	810	C.	10	Very high	$Ca-SO_4$	Very bad	Fair.
Sanford & Claverias	Nov. 11	11	20 S.	17 E.	150	6	192	1,640	210	1,220	3,000	1,300	1,300	C.	6	do	do	do	Do.
Joseph Mouren	do	11	20 S.	17 E.	1,200	0	147	800	85	810	1,500	840	360	C.	19	High	do	do	Good.
J. E. Howard	Nov. 1	8	14 S.	18 E.	58	3	137	5	65	195	280	210	30	?	30	Moderate	$Ca-CO_3$	Poor	Do.
Garrison Bros	Nov. 8	34	16 S.	18 E.	35	0	294	Tr.	5	22	310	70	300	N. C.	6	do	$Na-CO_3$	Bad	Fair.
H. Jensen	do	1	17 S.	18 E.	24	0	287	Tr.	10	79	310	130	230	N. C.	8	do	do	Fair	Do.
Burrell estate	do	2	17 S.	18 E.	1,200	Tr.	417	Tr.	135	47	610	80	650	N. C.	3.4	High	do	Very bad	Poor.
Do	do	9	17 S.	18 E.	80	Tr.	488	20	20	95	510	120	470	N. C.	4	do	do	do	Do.
H. O. Marshall	do	15	17 S.	18 E.	600	6	457	Tr.	125	46	640	100	690	N. C.	3	do	do	do	Do.
Wheatville school district	do	17	17 S.	18 E.	110	0	322	176	120	140	760	170	650	N. C.	5	do	do	do	Do.
Joseph Mouren	Nov. 10	6	18 S.	18 E.	115	Tr.	114	1,110	145	1,000	2,000	1,120	490	C	12	Very high	$Ca-SO_4$	do	Fair.
Manuel Nunez	do	9	18 S.	18 E.	80	3	94	1,010	125	890	1,800	920	560	C.	12	High	do	do	Do.
Do	Nov. 12	14	18 S.	18 E.	2,250	12	351	5	280	28	810	60	920	N. C.	3	do	Na-Cl	do	Poor.
Pacific Coast Oil Co	Nov. 10	36	18 S.	18 E.	1,178	3	153	256	40	42	610	70	550	N. C.	8	do	$Na-SO_4$	do	Fair.
Pacific Consolidated Oil Co	Nov. 3	2	13 S.	19 E.	100	0	92	Tr.	10	77	150	130	20	N. C.	200	Low	$Ca-CO_3$	Fair	Good.
H. O. Davis	do	5	13 S.	19 E.	70	0	220	5	115	237	410	270	150	?	18	Moderate	do	Poor	Fair.
H. H. Fisher	do	13	13 S.	19 E.	44	0	72	Tr.	10	48	130	100	30	N. C.	75	Low	do	Fair	Good.
Mrs. G. E. Thornton	Nov. 7	29	14 S.	19 E.	20	0	141	5	40	125	210	180	70	N. C.	40	Moderate	do	do	Do.
Do	do	29	14 S.	19 E.	90	0	152	5	50	173	270	220	40	?	40	do	do	Poor	Do.
Mrs. Eva Rowntree	Nov. 8	5	17 S.	19 E.	75	0	93	Tr.	45	48	200	100	120	N. C.	20	do	$Na-CO_3$	Fair	Do.
Miller & Lux	Oct. 23	34	12 S.	12 E.	229	0	68	2,020	100	1,860	3,200	1,900	600	C.	14	Very high	$Ca-SO_4$	Very bad	Fair.
Do	do	19	11 S.	13 E.	22	0	144	136	210	340	700	370	300	?	10	High	Na-Cl	Bad	Do.
Do	do	33	11 S.	13 E.	437	0	176	400	685	380	1,900	410	1,500	?	3	do	do	Very bad	Poor.
Do	do	9	13 S.	13 E.	202	0	144	1,380	150	1,320	2,400	1,350	600	C.	11	Very high	$Ca-SO_4$	do	Fair.
Do	Nov. 1	23	14 S.	13 E.	233	3	150	1,680	145	1,250	2,900	1,300	1,080	C.	8.5	do	do	do	Do.
Belmore Land & Water Co	do	5	15 S.	13 E.	284	Tr.	205	1,810	160	1,130	3,100	1,160	1,600	C.	6.7	do	$Na-SO_4$	do	Poor.
Miller & Lux	Oct. 23	8	12 S.	14 E.	40	0	73	10	15	40	15	90	70	N. C.	40	Low	$Na-CO_3$	Good	Do.
Pacific Coast Oil Co	Oct. 31	22	13 S.	14 E.	532	Tr.	176	305	115	80	950	110	860	N. C.	6	High	$Na-SO_4$	Very bad	Fair.
S. E. Ward	Nov. 3	19	13 S.	20 E.	95	0	82	Tr.	5	43	130	90	40	N. C.	50	Low	$Ca-CO_3$	Good	Good.
Fresno Brewing Co	Nov. 5	10	14 S.	20 E.	100	0	68	Tr.	5	51	120	100	15	N. C.	200	do	do	Fair	Do.
Do	do	10	14 S.	20 E.	210	0	76	Tr.	10	59	130	110	50	N. C.	45	do	do	do	Do.
Valley Ice Co	do	14	14 S.	20 E.	105	0	142	Tr.	10	115	190	160	20	N. C.	140	Moderate	do	do	Do.
J. W. Crawford	Nov. 8	21	17 S.	20 E.	46	0	35	Tr.	5	20	90	70	20	N. C.	100	Low	do	Good	Do.
Fresno Flume & Lumber Co	Nov. 4	9	13 S.	21 E.	(c)	0	134	Tr.	15	99	190	150	40	N. C.	65	Moderate	do	do	Do.
M. F. Tarpey	do	21	13 S.	21 E.	263	0	142	Tr.	10	116	190	170	20	N. C.	200	do	do	Fair	Do.
Do	do	28	13 S.	21 E.	500	0	153	Tr.	15	122	210	170	30	N. C.	140	do	do	do	Do.
St. George Winery	do	5	14 S.	21 E.	95	0	104	Tr.	5	86	150	140	10	N. C.	400	Low	do	do	Do.
Charles Ochs	do	9	15 S.	21 E.	60	0	106	Tr.	60	107	240	160	90	?	35	Moderate	do	do	Do.
Magnolia school district	do	11	15 S.	21 E.	20	0	93	Tr.	30	54	180	100	80	N. C.	30	do	$Na-CO_3$	do	Do.
R. B. Baird	do	32	13 S.	22 E.	75	0	40	Tr.	5	33	90	60	10	N. C.	400	Low	$Ca-CO_3$	Good	Do.
O. E. Wood	do	3	15 S.	22 E.	85	0	40	Tr.	5	45	90	80	0	N. C.	400	do	do	do	Do.
Southern Pacific Co	Nov. 18	26	16 S.	22 E.	95	0	167	Tr.	60	200	290	230	30	?	35	Moderate	do	Poor	Do.

[a] C., corrosive; N. C., noncorrosive; ?, corrosion uncertain or doubtful.
[b] One of four wells 430 to 480 feet deep.
[c] Two wells 45 and 75 feet deep.

TABLE 51.—*Mineral analyses of ground waters in Fresno County.*

[Parts per million unless otherwise designated.]

Owner.	Date.	Location. Sec.	Location. T.	Location. R.	Depth of well (feet).	Determined quantities. Silica (SiO_2).	Determined quantities. Iron (Fe).	Determined quantities. Calcium (Ca).	Determined quantities. Magnesium (Mg).	Determined quantities. Sodium and potassium (Na+K).	Determined quantities. Carbonate radicle (CO_3).	Determined quantities. Bicarbonate radicle (HCO_3).	Determined quantities. Sulphate radicle (SO_4).	Determined quantities. Chlorine (Cl).	Determined quantities. Total solids.	Computed quantities. Scale-forming ingredients (s).	Computed quantities. Foaming ingredients (f).	Computed quantities. Probability of corrosion (c).[a]	Computed quantities. Alkali coefficient (k) (inches).	Classification. Mineral content.	Classification. Chemical character.	Classification. Quality for boilers.	Classification. Quality for irrigation.	Analyst.
Pacific Coast Oil Co	......	14	15 S.	15 E.	756	......	......	64	8	291	0	210	536	67	(b)	230	790	N. C.	18	High	$Na-SO_4$	Very bad	Fair	Pacific Coast Oil Co.
J. G. James Co	Nov. 1, 1910	10	14 S.	16 E.	550	......	0.75	28	3.6	c 353	0	179	318	266	1,138	120	960	N. C.	6.3	do	Na-Cl	do	do	F. M. Eaton.
F. C. Stillman	Nov. 7, 1910	5	17 S.	16 E.	160	......	.35	199	129	c 20	0	191	711	122	1,826	830	50	C.	17	do	$Ca-SO_4$	do	do	Do.
Joseph Mouren	Nov. 11, 1910	11	20 S.	17 E.	1,200	28	.35	127	101	208	0	148	895	85	1,700	570	560	C.	15	do	do	do	do	Walton Van Winkle.
Sanford & Claverias	do	11	20 S.	17 E.	150	......	.30	232	161	......	0	220	718	196	3,210	980	460	C.	10	Very high	do	do	do	F. M. Eaton.
Southern Pacific Co	Oct. 13, 1891	7	14 S.	18 E.	(d)	e 45	......	18	5	37	0	144	6	14	196	105	100	N. C.	22	Moderate	$Na-CO_3$	Fair	Good	Southern Pacific Co.
Manuel Nunez	Nov. 12, 1910	14	18 S.	18 E.	2,250	......	Tr.	9.5	1.8	c 320	0	403	4.9	279	872	60	860	N. C.	2.9	High	Na-Cl	Very bad	Poor	F. M. Eaton.
Pacific Coast Oil Co	......	36	18 S.	18 E.	1,160	e 21	......	28	2	186	0	150	289	41	f 652	105	500	N. C.	14	do	$Na-SO_4$	do	Fair	Pacific Coast Oil Co.
Southern Pacific Co	June —, 1900	5	13 S.	19 E.	115	e 72	......	12	5	18	0	60	3	26	166	115	50	N. C.	80	Moderate	$Ca-CO_3$	Fair	Good	Southern Pacific Co.
Do	July 8, 1905	10	14 S.	20 E.	225	e 68	......	33	15	33	0	134	25	53	294	190	90	?	40	do	do	do	do	Do.
Do	June 21, 1902	10	14 S.	20 E.	130	e 74	......	31	14	33	0	158	8	27	296	190	90	N. C.	30	do	do	do	do	Do.
Santa Fe Ry. Co	Oct. 1, 1902	10	14 S.	20 E.	......	e 67	......	18	8	30	0	136	7	18	216	135	80	N. C.	30	do	do	do	do	Kennicott Water Softener Co.
Fresno Brewing Co	Nov. 5, 1910	10	14 S.	20 E.	100	......	.38	10	5.3	c 11	0	72	2.9	6.0	178	90	30	N. C.	85	do	do	Good	do	F. M. Eaton.
Do	do	10	14 S.	20 E.	210	74	.01	10	5.5	16	0	76	8.7	3.8	169	115	40	N. C.	60	do	do	Fair	do	Walton Van Winkle.
Southern Pacific Co	June 13, 1892	1	17 S.	20 E.	630	e 16	......	4	1	55	0	115	5	21	159	30	150	N. C.	15	do	$Na-CO_3$	Good	Fair	Southern Pacific Co.
Miller & Lux	Oct. 23, 1910	8	12 S.	14 E.	40	......	.10	13	2.3	c 25	Tr.	82	8.2	14	140	90	70	N. C.	40	Low	do	do	Good	Do.
Pacific Coast Oil Co	Oct. 31, 1910	22	13 S.	14 E.	532	......	.60	30	4.1	c 372	20	152	541	128	1,268	125	1,000	N. C.	9	High	$Na-SO_4$	Very bad	Fair	Do.
M. F. Tarpey	Nov. 5, 1910	28	13 S.	21 E.	500	......	.35	26	12	c 16	0	159	3.7	10	210	150	45	N. C.	60	Moderate	$Ca-CO_3$	Fair	Good	F. M. Eaton.
Southern Pacific Co	Dec. 30, 1901	15	14 S.	22 E.	60	e 12	......	8	2	46	0	86	3	38	152	40	120	N. C.	20	do	$Na-CO_3$	Good	do	Southern Pacific Co.
A. R. Gilstrap	Nov. 18, 1910	27	16 S.	22 E.	84	......	.30	38	7.7	c 0	0	99	9.9	24	245	175	0	?	85	do	$Ca-CO_3$	Fair	do	F. M. Eaton.
Southern Pacific Co	Apr. 2, 1902	27	16 S.	22 E.	100	e 48	......	25	6	12	0	89	6	24	165	130	30	?	85	do	do	do	do	Southern Pacific Co.
Santa Fe Ry. Co	Oct. 1, 1902	27	15 S.	23 E.	......	e 40	......	22	8	27	0	136	6	18	188	120	70	N. C.	35	do	do	do	do	Kennicott Water Softener Co.

[a] C., corrosive; N. C., noncorrosive; ?, corrosion uncertain or doubtful.
[b] Organic and volatile matter, 36 parts.
[c] Computed.
[d] Wells 60 and 640 feet deep.
[e] Including oxides of iron and aluminum.
[f] Organic and volatile matter, 11 parts.

WELL RECORDS.

The accompanying well records secured by the Geological Survey in 1906 and earlier represent practically all of the important wells in existence at that date and many others that were examined to determine water levels and quality of water. Developments that have taken place since that date are not represented.

TABLE 52.—*Records of wells in Fresno County.*

Owner.	Location. Section.	Township south.	Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.[a]	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
Miller & Lux	33	10	13	1902	Bored, 7 inches	14	10		Hand	D, S			
Do	6	11	13	1903	do	480	0		Artesian	S			
Do	10	11	13	1900	Dug, 4.5 by 4.5 feet	22	10		Wind	D, S			
A. D. Johns	7	11	13	1902	Dug, 2 feet	10	7	70	Hand	D, S			
C. W. Slayton	14	11	12	1905	Dug, 2.5 feet	14	7		Wind	D, S			
F. B. Marks	13	11	12	1895	Dug, 1.5 feet	15	7		do	D, S			
J. Glidden	24	11	12	1893	Dug, 2 feet	28	7		do	D, S			
R. D. Conrow	24	11	12	1894	Dug, 1.75 feet	15	7	71	Hand	D, S			
Geo. W. Martin	24	11	12	1905	Dug, 2 feet	12	7	70	do	D			
Pacific Coast Oil Co	23	11	12	1905	Bored, 10 inches	408	10						
Miller & Lux	19	11	13	1905	Dug, 2 feet	22	7		Wind	D, S			
Do	30	11	13	1887	Bored, 8 inches	93	7.5		Horse	S			
Do	24	11	13	1899	Dug, 5 by 5 feet	16	10		Wind	D, S			
Do	24	11	13		Bored, 8 inches	65	10	72	Hand	S			
Do	33	11	13	1894	Bored, 7 inches	437	0	70	Artesian	S	4		
Do	8	12	14	1882	do	40	10		Wind	D			
Do	28	12	14		Dug, 5 by 5 feet	22	10		do	S			
Southern Pacific Co	29	12	14		Bored, 8 inches	300	0	67	Steam	N			
Miller & Lux	9	13	13		Bored, 7 inches	202	80		Horse	S			
Do	34	12	12		do	229	73		Wind, horse	S			
Do	22	12	11		do	169	80		do	S			
Do	34	13	12		do	260	145		Horse	S			
Do	34	13	14		do	240	60		do	S			
Pacific Coast Oil Co	22	13	14	1905	Bored, 10 inches	700	0	78	Artesian	I, D, B	6		
A. J. Arnaudon	31	13	15	1900	Bored, 8 inches	285	18		Wind	D			[b] $1,500.00
Southern Pacific Co	31	13	15	1889	do	640	0	78	Artesian, steam	D	[c] 7		
Bliss Bros	35	9	14	1875?	Bored, 6 inches	25							

[a] D, domestic; S, stock; I, irrigation; B, boilers; N, not used; W, winery; R, roads.
[b] Cost of well and equipment combined.
[c] Yield estimated or statement of owner taken.

TABLE 52.—*Records of wells in Fresno County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
Stearns & Hysinger	12	14	14	1904	Bored, 16 inches	200	40		Steam				
A. J. Arnaudon	21	14	14	1889	Bored, 8 inches	190	33		Hand	S		$400	
C. Boyer	33	14	14	1889	do	175	90		Horse	S			
Miller & Lux	26	14	13		Bored, 7 inches	124	93		do	S			
Do	33	14	13		do	229	133		do	S			
Herminghause Ranch	2	14	15		Bored, 8 inches	750	0	78	Artesian	S, I	20		
Do	30	13	16			650	0		do	S	*a* 10		
J. G. James Co	10	14	16	1887	Bored, 7 inches	800	0	78	do	S	*a* 16	1,650	
Southern Pacific Co	14	14	16		do	200	7.5		Hand	D			
J. G. James Co	7	14	17		Dug	11	9	64	do	D, S			
Mrs. G. W. Bryan	36	13	17			120	15		Gas	I			*b*$2,500.00
Do	36	13	17			70	15		do				
James Cull	25	13	17		Bored, 5 inches		12		Wind	D			
A. E. Wood	19	13	18		Hydraulic, 2 inches	50	10	72	Hand	D, S			
Peter J. Wolf	29	13	18		do	55	11		do	D, S			
Sharon estate	21	13	18		Bored, 7 inches	60	11	70	Wind, horse	D, S			
Do	21	13	18	1904	Bored, 10 inches	200?	12		Gas	I	*a* 300		
Do	21	13	18	1904	do	200?	12		do	I	*a* 300		
Henry Sahm	33	13	18			50	10		Hand	D, S			
Kutner & Goldstein	32	13	18	1905	Bored, 16 inches	160	15		Gas	I			
Do	32	13	18		Bored, 8 inches	42	11	72	Hand	D, S			
Mr. Smith	5	14	18		Bored, 1.5 inches	20	11		do	D			
J. E. Howard	8	14	18	1905	Hydraulic, 2 inches	58	12		do	D, S		20	
James Garner	9	14	18		Bored, 2 inches	69	12		do	D		25	
Southern Pacific Co	7	14	18		Bored, 8 inches	640	6		Wind, steam	B			
E. A. Manning	32	14	18	1894	Hydraulic, 2inches	100	7		Hand	D, S			
Do	31	14	18	1894	do	100	6		do	D, S			
J. G. James Co	10	15	17	1886-7	Bored, 8 inches	700	0		Artesian	S	Small.	1,370	
Do	9	15	17	1886-7	do	800	0	74	do	S	40	1,850	
Do	12	15	16	1886-7	Bored, 7 inches	800	0	77	do	D, S	10	1,650	
Do	25	15	16	1886-7	Bored, 8 inches	825	0	76	do	I, S		1,700	
Do	26	15	16		Dug, 1.5 feet	25	10		Wind	D, S			
Do	34	15	16		Bored, 5 inches	24	15	68	Hand	S			
Do	28	15	16		do	34	11		Not raised	N			
Do	29	15	16	1890?	do	70	12		Hand	D, S			
Do	19	15	16	1886-7	Bored, 8 inches	700	0	79	Artesian	S	*a* 2	1,370	
Do	18	15	16		Bored, 5 inches	60	13		Wind	S			
School district	18	15	16		Bored, 2 inches	60	14	67	Hand	D			

J. G. James Co.	13	15	15		Bored, 5 inches	50	8		Wind	S.			
J. N. Daniels	12	15	15		Dug	20	13		do	S.			
Pacific Coast Oil Co.	11	15	15	1904	Bored, 8 inches	733	0	76	Artesian, steam	D, B	11		
Sheep camp	3	15	15		Bored, 5 inches	9	7	72	Not raised	N			
J. G. James Co.	35	15	16		do	43	23	66	Wind	S.			
Do	36	15	16		do	42	10.5		do	D, S.			
Do	32	15	17		Dug	15	12		do	S.			
Do	25	15	17	1886-7	Bored, 8 inches	750	0	80	Artesian	S.	*a* 31	1,560	
Abandoned ranch	12	16	16		Bored, 10 to 8 inches.	+200	13		Not raised	N			
Miss Miller	20	16	17		Bored, 7 inches	70	11	70	Hand	D, S			
Hellum & Co	15	16	17	1903	do	83	13		Wind	S.			
Do	14	16	17	1903	Bored, 5 inches	80	12	68	Wind, horse	D, S			100.00
Do	14	16	17	1904	Bored, 10 inches	690	0	75	Artesian	I.	*a* 8		
Mrs. Yates	22	16	17	1898	Bored, 7 inches	50	11		Wind	D, S			
New Hope school district	27	16	17	1895	Bored, 5 inches	60	12		Hand	D			
Pacific Coast Oil Co.	8	17	17	1905	Bored, 8 inches	1,100	0		Artesian	B			
Burrell estate	5	17	18	1896	Bored, 7 inches	50	13		Hand	S.			
Marks Bros.	8	17	18	1895?	do	80	15	71	Wind	D, S			50.00
Burrell estate	9	17	18	1893	do	80	12		do	D, S		125	65.00
J. R. Hite	17	17	18		do	122	12	70	do	D, S		175	60.00
Wheatville school district	17	17	18		do	110	12	72	do	D			
J. R. Hite	15	17	18	1890	Bored, 8 inches	600	0	76	Artesian	I, S			
Burrell estate	10	17	18		Bored, 7 inches	75	12		Wind	D, S			
Josephine Smith	34	16	18	1890	Dug, 2½ feet	35	12		do	D			
Burrell estate	2	17	18	1888	Bored, 8 inches	1,200	0	78	Artesian	D, S			
H. Jensen	1	17	18		Dug, 2 feet	24	12	69	Wind	D, S			
C. L. Cameliones	6	17	19	1904	Bored, 5 inches	52	12		do	D			
L. E. Vance	6	17	19	1891?	do	56	14	70	Wind, hand	D, S			
Ipsen Bros.	6	17	19	1904	do	77	15		Hand	D, S		75	
Mrs. Eva Rowntree	5	17	19	1890?	do	75	15		Wind	D, S			
Henry Jensen	4	17	19		do	54	12		Hand	S.		39	
Mr. Browning	17	17	19		Bored, 8 inches	700	0	77	Artesian	S.	17		
William Johns estate	21	17	19	1890	do	1,500	0	82	do	S.	23	1,500?	
A. J. Vancleef	22	17	19		Bored, 5 inches	40	10	71	Wind	D		25	65.00
C. W. Baker	32	17	19	1903	do	37	8		Hand	D, S			
William Johns estate	28	17	19	1890	Bored, 8 inches	1,200	0	80	Artesian	S.	*a* 15	1,200	
Peter Gobby	27	17	19	1903	Dug, 1½ feet	30	8		Wind	D			75.00
J. Q. Hancock	23	17	19		Bored, 5 inches	80	9	69	do	D, S			
W. J. Brawner	24	17	19	1905	do	82	6	70	Hand	D		57	
R. S. Gobbe	19	17	20		do	18	6	72	Wind	D, S			85.00
J. Fleharty	29	17	20		Dug, 2 feet	16	10		Hand	D			
J. N. Fleharty	29	17	20		Bored, 5 inches	55	10	70	do	D		27	
J. W. Crawford	21	17	20	1903	do	46	10		do	D, S		23	
L. B. Wheeler	22	17	20	1880	do	56	16		Wind	D, S		30	40.00
A. McDonald	1	17	20	1885	Bored, 7 inches	40	10		Hand	D, S		25	
Southern Pacific Co.	1	17	20		Bored, 8 inches	700	0	80	Artesian, steam, wind.	B	*c* 1		
J. E. Lewis	21	17	20	1902	Bored, 5 inches	118	13.5	70	Hand	D, S		75	
P. L. Rousseau	27	17	20	1903	do	48	8?	69	Wind	D, S		28	45.00
H. E. Center	26	17	20		do	39	4	70	Hand	D		20	

a Yield estimated or statement of owner taken. *b* Cost of well and equipment combined. *c* Normal flow without pumping.

TABLE 52.—*Records of wells in Fresno County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
L. G. Boggs	24	17	20		Bored, 5 inches	40	8	71	Hand	D			
Laguna de Tache ranch	24	17	20		do	80	8		do	D			
Mr. Fike	19	17	21		do	46	8	70	do	D			
Grant school district	19	17	21		do	32	8	70	do	D			
Mr. Hurley	19	17	21		do	60	10		Wind	D, S			
E. P. Blanchard	20	17	21		do	60	9	68	Hand	D			
J. W. Buble	21	17	21		do	73	9	69	do	D		$39	
L. A. Nares	21	17	21		Bored, 6 inches	90	8	66	do	D, S			
Nares & Saunders	22	17	21	1902	Bored, 10 inches	200	5		Gas	D	5		
J. H. Cleveland	28	17	21	1900	Bored, 5 inches	32	7.5		Hand	D			
D. F. Lumsden	29	17	21	1901	do	86	9	69	do	D		45	
J. R. Ryder	25	17	20		Bored, 1½ inches	30	8	70	do	D			
J. E. Woodworth	34	17	20		Bored, 5 inches	46	8	68	do	D		23	
Leguna school district	27	17	20		do	54	8	70	do	D			
James Hay	27	17	20		do	46	4		do	D		31	
Mr. Molen	3	18	20		do	50	10	72	do	D			
Manuel de Mecedo	3	18	20		do	30	13		do	D			
Laguna de Tache ranch	4	18	20		Bored, 7 inches	45	11.5	70	do	S			
Joseph Jubrizil	5	18	19		do	43	14	70	Wind	S, D			
A. H. Brown	6	18	19	1889	Bored, 5 inches	100	8		do	D			
Chas. W. Brown	6	18	19	1888	do	106	8		do	D, S			
Mr. Awalt	6	18	19	1889	Bored, 7 inches	100	11		do	D, S		125	$50.00
Mr. Goodrich	1	18	18	1902	Bored, 5 inches	87	12	71	Hand	D, S			
H. Clausen	35	17	18	1895?	Bored, 7 inches	62	16		Wind	D, S		100	
W. Corbeley	34	17	18		Bored, 5 inches	48	16		Hand	D, S			
T. Cowan	27	17	18	1890	Bored, 7 inches	114	16		Wind	D, S		175	
Henry Munson	21	17	18	1897	do	122	9	70	do	D			
Do	22	17	19	1898	Bored, 6 inches	24	13	70	do	S			
Manuel Nuñez	9	18	18		Bored, 7 inches	80	29		Horse	S			
Joseph Mouren	6	18	18	1891	do	115	35		do	S		200	
Joseph Taix	12	18	17	1897	do	114	42		Wind	S		200	50.00
Mrs. Cravelio	24	17	17		Bored, 6 inches	100	38?		Horse	S			
H. R. McCord	14	18	16	1888	Bored, 7 inches	250	73		Wind	S, D			
Pedro Arriet	18	18	16	1902	do	135	120		Horse	S		147	
F. G. Ladd	12	18	15	1903	do	256	160		do	S			
Sheep camp	26	18	18		do	60	36		Not raised	N			
Pacific Coast Oil Co	36	18	18	1903	Hydraulic, 8 to 6 inches.	1,178	20?	80	Compressed air	B	7	2,000	

Sheep camp	19	18	19		Bored, 6 inches	52	27		Not raised	N			
Do	28	18	19		Dug, 6 by 8 feet	20	14		Hand	S			
L. Ballou	14	19	17	1890	Bored, 8 inches	140	138		Wind, horse	N			
Eugene Cosgriff	4	20	17		Bored, 7 inches	160	140		Horse	S		300	
E. B. Martin	6	20	17	1889	Bored, 8 inches	160	140		Wind, horse				
Pleasant Valley Stock Farm	32	20	16		Bored, 7 inches		0	68	Artesian	I	9		
Do	32	20	16		Bored, 12 inches		0	68	do	I	2		
Do	32	20	16		Bored, 7 inches		0	68	do	I	a 5		
Do	32	20	16		Bored, 12 inches		0	68	do	I			
Coalinga Consolidated Water Co	16	20	15	1898	(b)	275–300	230	76	Steam	B	a 18		
Valley Water Co. c	12	20	14	1901	Bored, 6 inches	300	150	76	do	B	a 10		
J. A. McClurg	35	20	14		Bored, 8 inches	720	0		Artesian	D	1		
Bunting Iron Works	32	20	15	1905	Bored, 7⅝ inches	255	110		Steam	D, S	3		
Do	32	20	15	1905	Bored, 12 inches	268	110		do	D, S			
J. R. Baird	1	21	16	1901	(d)	18–56	0		Artesian	D, I	a 25		
W. J. McFee	30	20	17		Bored, 7 inches		210		Not raised	N			
Joseph Mouren	11	20	17	1890	do	150	130	73	Wind	S			
W. J. Dickey	8	20	18	1890	Bored, 8 inches	180	140?		do	N			
	28	19	19	1889	Bored, 6 inches	1,100	0		Artesian	S	Small.		
Marion Heinlen	5	19	20		do	500	0	76	do	S	3		
Do	5	19	20		Bored, 5 inches	100	0	71	do	S	Small.		
Antone Neunes	22	18	20	1902	Bored, 2 inches	128	0		do	D, S	Small.		
A. A. DeGroat	22	18	20	1903	Hydraulic, 2 inches	140	0	70	do	D, S	Small.		
Thomas Fanucken	32	18	20	1900	Bored, 5 inches	105	0	70	do	D	Small.		
Mary Taylor	32	18	20	1899	do	100	0	70	Artesian, hand	D, S	Small.		
A. K. Taylor c	32	18	20	1899	do	130	0	69	Artesian	D, S	Small.		
R. A. Morrison	33	18	20	1904	do	138	0		do	D, S	Small.		
J. A. Green	32	18	20	1896	do	96	0	70	Artesian, hand	D, S	Small.	85	
Rhodes estate	28	18	20	1889	Bored, 8 inches	700	0	76	Artesian	I, S	a 20		
Manuel Perera	29	18	20		Bored, 2 inches	120	8		Wind	D, S			
Frank Sharpels	16	18	20	1898	Bored, 5 inches	170	10		Hand	D			4.00
J. Sutherland	28	18	20	1894	Bored, 2 inches	530	0		Artesian	D, S	Small.		
J. D. Patterson	22	18	20	1892	Bored, 5 inches	106	3		Hand	D		99	
W. A. Long	18	18	21		do	33	6		do	D, S		16	4.00
J. Sutherland	15	18	20	1899	do	96	3		do	D, S		65	3.00
C. H. Smith	32	17	21	1897	do	30	10		do	D, S			4.50
R. V. Daggett	4	18	21	1880	Bored, 6 inches	40	10		do	D, S			2.25
P. C. Phillips	28	17	21	1899	Bored, 5 inches	48	13.5		do	D			6.00
Judson Stutson	6	13	19	1883	Bored, 7 inches	115	60		Wind	D, S			
Southern Pacific Co	5	12	19	1887	Dug, 12 feet; bored, 8 inches.	140	85		Steam	B			
E. J. Bullard	31	12	20	1886	Bored, 8 inches		70		Wind	D, S			
Do	5	13	20		do		100		do	D, S			
J. H. Funck	3	13	20	1892	Bored, 7 inches	80	32		Hand	D			
J. H. Randel	34	12	20		Bored, 6 inches	70	60		Horse	D, S			
E. J. Lane	22	12	20	1894	Bored, 8 inches	99	85		Wind	D, S		145	41.00
J. P. Williams	14	12	20		Bored, 6 inches	115	90		do	D, S			
A. B. Ball	7	12	21	1892	do	145	80		do	D, S			
Milo Rowell	5	12	21	1880	Bored, 7 inches	130	60		do	D			174.00
V. B. Cobb	9	12	21		Dug	47+	33		Hand	D, S			

a Yield estimated or statement of owner taken.
b Two wells, 7⅝ inches; one well, 9⅝ inches; and one well, 11⅝ inches diameter.
c Two wells.
d Four 6-inch and four 8-inch wells.

TABLE 52.—*Records of wells in Fresno County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
J. M. Heiskell	8	12	21	1880	Bored, 7 inches	100	63		Wind	D, S			
Fresno National Bank	15	12	21	1889	Bored, 8 inches	86	18		do	D, S			$30.00
Bank	11	12	21		Dug	40	20		Hand	D, S			5.00
T. P. Nelson	14	12	21	1888	Bored, 6 inches	25	13		do	D, S			5.00
J. E. Dickerson	23	12	21	1880	Bored, 8 inches	50	11		Wind	D, S			
J. B. Collins	24	12	21	1880	Bored, 6 inches	54	14		Hand	D, S			
Jack Simpson	22	12	22	1898	Dug	25	20		Wind	D		$10	6
Marvin Simpson	27	12	22	1899	do	25	24		do	D, S			
	34	12	22		do	17	14		Horse	S			
D. C. Sample	29	12	22		do	25	24		Wind	D, S			25.00
Do	32	12	22		do	40	30		do	D, S			55.00
J. W. Potter	26	12	21	1899	Bored, 8 inches	50	12		Hand	D, S			5.00
Do	26	12	21	1877	do	60	20		Wind	D, S			35.00
Do	34	12	21	1892	Bored, 6 inches	50	12		Hand	D, S			
A. Henderson	33	12	21	1888	Bored, 5 inches	77	10		Wind	D, S			
H. B. Bissell	28	12	21		Bored, 8 inches		12		do	D, S			
F. E. Brown	20	12	21	1890	Bored, 7 inches		34		do	D, S			
J. W. Brown	18	12	21	1882	do	100	45		do	D, S			
Gudlip Ambrosia	24	12	20	1891	Bored, 6 inches		68		do	D, S			
Harry Maupin	25	12	20	1885	do	113	48		do	D, S		113	90.00
Chas. A. Owens	30	12	21	1879	Dug	90	26		do	D, S			
	5	13	21	1896	Bored, 5 inches	50	15		Hand	D, I			5.00
Gus Ploetz	6	13	21	1895	do	80	28		Wind	D			
	11	13	20		do		28		Hand	D			
H. V. Parker	10	13	20	1891	Bored, 8 inches	105	30		Wind	D, S			
J. Wallers	10	13	20	1890	Bored, 6 inches	65	24		Hand	D			
California Bank	11	13	19	1882	Bored, 7 inches	112	38		Wind	D, S			53.00
Do	11	13	19	1897	Bored, 5 inches	83	38		do	D, S		58	
Mrs. Thornton	19	13	19	1888	Bored, 6 inches	60	20		do	D, S			
California Bank	23	13	18	1898	Bored, 5 inches	100	22		do	D, S		100	50.00
Kennedy & Owen	25	13	18		do	40	16		Hand	S			3.50
Mr. Williams	29	13	19		Bored, 7 inches	35	21		do	D, S			
Lafayette Pearson	26	13	19	1892	Bored, 2 inches		16		do	D, S			3.00
Balfour Guthrie & Co.	25	13	19	1888	Bored, 5 inches		24		Wind	D, S			
Mrs. E. G. McCardle	24	13	19	1900	Bored, 6 inches	96	27		Hand	D			
S. E. Ward	19	13	20	1892	do	95	25		do	D		45	15.00
B. T. Tipton	20	13	20		do	70	16		do	D			3.00
J. Mills	29	13	20	1892	Bored, 5 inches	80	8		do	D		40	25.00

M. Dunlavey	33	13	20	1895	do	90	7		do	D			
C. D. Edgerly	27	13	20	1890	Bored, 2½ inches	85	10		Wind	D			25.00
Mr. Bailey	28	13	20	1896	Bored, 2 inches	55	9		Hand	D			
	21	13	20		Bored, 6 inches		17		Wind	D			
T. C. White	22	13	20		Bored, 7 inches	50	18		do	D			
Wm. Bitner	14	13	20		Bored, 2½ inches		15		Hand	D			5.00
F. M. Merrit	14	13	20		Bored, 7 inches	+100	13		Wind	D, S			
Paul Leonhart	19	13	21	1889	Bored, 1¾ inches	70	9		Hand	D		30	5.00
Olsen estate	19	13	21	1899	Bored, 6 inches	80	7		Steam, wind	W, D		100	
F. M. Roessler	30	13	21	1890	Bored, 2 inches	50	6		Wind	D			
Eggars estate					Bored, 8 inches		6		Steam	W, D	2		
P. H. McGarry	21	13	21	1891	Bored, 5 inches	80	6		Hand	D		40	
M. F. Tarpey	21	13	21		Bored, 2 inches	110	7		Wind	D, S		33	
Andrew Palm	15	13	21	1891	do	85	6		Hand	D		25	5.00
J. W. Sharer	15	13	21	1890	Bored, 6 inches	80	9		do	D, S			
R. T. Owen	8	13	21	1881	Bored, 7 inches	90	13		Wind	D			
C. R. Damon	8	13	21	1898	Bored, 5 inches	54	10		Hand	D, S		175	18.00
Cates estate	2	13	21	1894	Bored, 7 inches	40	10		Wind	D, S			5.00
J. D. Reyburn	11	13	21	1892	do	85	12		do	D, S		85	125.00
E. E. Irwin	14	13	21	1885	Bored, 8 inches	85	9		do	D, S			65.00
R. G. Hewitt	14	13	21	1892	Bored, 2 inches	90	12		Hand	D, S			$5.00
A. J. Cass	14	13	21	1891	do	60	9		do	D		$30	8.00
L. M. Fincher	22	13	21	1880	Bored, 8 inches	75	6		do	S			6.00
Mr. Herman	24	13	21	1897	Bored, 2 inches	40	8		do	D, S		12	6.00
McDonald estate	18	13	22	1877	Dug	80	15		do	D, S			
Sam Ebe	8	13	22		do		11.5		do	D			
Sacramento Bank	8	13	22	1880	do	60	22		Wind	D			
B. F. Griffen	6	13	22	1880	do	50	28		do	D			40.00
Fresno Loan & Savings Bank	6	13	22	1882	do	37	18		do	D, S			14.00
T. C. White	9	13	22	1882	Bored, 8 inches	75	35		Hand	D			6.00
W. M. Harbison	10	13	22	1882	Bored, 6 inches	82	37		Wind	D, S			90.00
John Lee estate	19	13	22	1880	do	60	23		do	D, S			40.00
Alfred Beard	15	13	22	1885	Bored, 8 inches	75	38		do	D, S			35.00
John Snyder	35	13	22	1897	Bored, 7 inches	65	20		Hand	D, S		20	4.00
Chas. Lyman estate	34	13	22	1880	do	80	0		do	D			4.00
John Crol	9	14	22	1892	Bored, 6 inches	50	17		do	D, S		55	4.00
Dr. Chester Rowl	4	14	22	1897	Bored, 2 inches	95	14		do	D, S			
Sacramento Bank	6	14	22		Bored, 5 inches		9		do	D, S			4.25
R. B. Baird	32	13	22	1900	Bored, 2 inches	75	11		do	D, S		20	6.00
M. E. Laymensce	36	13	21	1891	do	60	8		do	D, S			
Cora Wickersham	3	14	22	1880	Bored, 7 inches		14		Wind	D, S			
Judge Wallace	35	13	21	1899	Bored, 2 inches	45	20		Hand	D		23	5.00
Judge Risley	6	14	22	1893	do	90	18		do	D, S		25	4.00
Bonner Vineyard Co.	11	14	21	1885	Bored, 8 inches	104	14		Horse	D, S		100	100.00
Fred Roeding	2	14	21	1887	Bored, 7 inches	110	17		Wind	D			
S. E. Mill	34	13	21	1899	Bored, 2 inches	70	12		do	D, S		23	46.00
Alice Treadwell	34	13	21	1887	do	85	10		Hand	D		40	4.00
W. F. Carrico	33	13	21	1885	Bored, 5 inches	78	9		do	D, S			4.50
C. D. Wright	5	14	21	1896	Bored, 2 inches	80	8		do	D			4.00
St. George Winery	5	14	21	1894	Bored, 10 inches	300	6		Steam	W	10	120	
Hughs Richler	6	14	21	1880	Bored, 2 inches	40	10		Hand	D, S		16	4.25
H. M. Rustigian	6	14	21	1891	do	60	12		do	D, S		25	4.00

TABLE 52.—*Records of wells in Fresno County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.			*Feet.*	*Feet.*	*°F.*			*Miner's inches.*		
J. M. Ellmore	15	13	22	1884	Bored, 8 inches	80	37		Wind	D, S		$80	$165.00
D. J. Dickey	25	13	20	1892	Bored, 7 inches	120	7		Gas, hand	D			
G. T. Hawley & Bro	25	13	20	1895	Bored, 2 inches	90	15		Hand	D, S			4.00
Mr. Hayes	25	13	20	1882	Bored, 7 inches	70	11		do	D, S			6.00
A. Vogel	34	13	20	1888	Bored, 4 inches	60	8		Wind	D, S			
John D. Rutledge	4	14	20	1897	Bored, 2 inches	75	6		Hand	D		16	4.00
T. L. Hunter	4	14	20	1898	Bored, 7 inches	55	5		do	D			
August Weihe	5	14	20	1897	Bored, 2 inches	35	7		do	D, S		8	3.50
Geo. Roeding	31	14	20	1900	Bored, 5 inches	93	12		Wind	D, S		73	50.00
Balfour Guthrie & Co	36	13	19	1880	do	30	17.5		do	D, S			4.00
	35	13	19		Bored, 2 inches		9		do	D, S			4.00
C. D. Smith	2	14	19	1890	Bored, 3 inches	70	8		do	D, S		42	50.00
I. C. Barman	18	14	19	1893	Bored, 1½ inches	85	6		Hand	D, S			3.50
Mat Asmussen	12	14	18	1881	Bored, 2 inches	70	8		do	D, S		21	3.25
	26	14	18		do	21	9			D, S			
Geo. P. Thornton	30	14	19	1893	do	80	8		Wind	D, S		24	47.00
Mrs. G. F. Thornton	29	14	19	1893	do	90	10		do	D, S		25	89.00
T. H. Burgess	15	14	19	1898	do	90	8		do	D, S		29	41.00
Herman Boyce	23	14	19		do		8		Hand	D, S			4.00
August Weye	27	14	19	1881	Bored, 6 inches	+80	7		Horse, wind	D, S		60	120.00
Burley Bros	27	14	19	1887	Bored, 7 inches	65	8		Wind	D, S		43	60.00
F. Duhring	34	14	19	1887	Bored, 6 inches		8		Hand	D			4.00
R. L. Epperson	36	14	19	1894	Bored, 2 inches	60	8		do	D		24	4.00
R. L. Dunham	36	14	19	1900	do	44	8		do	D, S		19	4.00
Mr. Parker	25	14	19	1898	do	70	6		do	D, S			4.00
J. J. Luce	12	14	19	1886	do	72	8		do	D, S			
Mrs. C. B. Lyman	1	14	19	1900	Bored, 6 inches	97	9		Wind	D, S		60	270.00
Victor Martin	9	14	20	1897	Bored, 2 inches	82	10		do	D			200.00
L. A. Gould	26	14	20	1890	do	80	7		do	D, S		40	150.00
H. H. Hass	16	14	20	1890	do	70	8		do	D, S			
O. D. Garrison	21	14	20	1888	do	120	8		do	D		48	4.25
T. H. Mallory	21	14	20	1900	do	69	10		do	D		28	300.00
E. Tommasini	29	14	20	1897	do	82	12		Hand	D, S			26.00
M. Robison	32	14	20	1890	do	70	10		do	D, S			3.00
G. C. Cheuvraut	33	14	20	1892	do	75	6		do	D, S		25	4.00
Richard White	33	14	20	1884	Bored, 8 inches	52	6		do	D, S		52	4.00
H. Roff	33	14	20	1880	do	90	9			D, S		80	
W. A. White	27	14	20	1900	Bored, 2 inches	57	10		Wind	D, S		225	45.00

E. F. Ball	14	14	20	1893	Bored, 6 inches	85	13		do	D, S			
Fresno Loan & Savings Bank	14	14	20	1880	do	65	8		do	D, S		65	
Estrella de Ora Drying Co	13	14	20	1891	Bored, 2 inches	75	5		Hand	D			
F. G. J. Schmidt	23	14	20	1886	do	40	10		do	D, S		20	3.25
Geo. A. Coughell	34	14	20	1885	do	+40	8		do	D, S			4.00
Henry Brooks	3	15	20	1885	do	80			do	D, S		32	4.00
Robert Boot	2	15	20	1880	Bored, 6 inches	90	12		do	D, S		90	4.00
Fresno National Bank	36	14	20	1890	Bored, 2 inches	24	8		Wind	D, S		37	72.00
	1	15	30		Bored, 6 inches		10.5		Hand	D, S			4.00
E. R. Bates	19	14	21	1890	Bored, 2 inches	82	10		Wind	D, S			250.00
Edwin Bullock	25	14	20	1899	Bored	70	12		do	D, S			35.00
Mrs. F. C. Ketchum	13	14	20	1890	Bored, 2 inches	60	12		Hand	D, S		24	4.00
R. J. Robinson	3	14	20	1900	do	73	10		do	D		29	4.25
Mr. Meyers	2	14	20	1890	do	30	15		do	D, S		15	4.25
Fresno County	2	14	20	1897	Bored, 7 inches		10		Gas	R	24		
D. J. Vaughn	12	14	20	1882	Bored, 5 inches	65	9		Wind	D		45	9.00
Fresno Vineyard Co	7	14	21		Bored, 6 inches		9		Gas	D			
M. E. Sherman	17	14	21	1899	do	40	10		Steam	I	100	206	1,300.00
Do	17	14	21	1899	do	120	10						
C. N. Brenenfeld	20	14	21	1895	Bored, 2 inches	80	9		Hand	D, S		25	5.00
James Rutheford	21	14	21	1891	do	100	9		do	D		40	3.00
J. W. Scott	29	14	21	1897	do	60	7		do	D, S		24	3.00
J. H. Larue	32	14	21	1886	Bored, 5 inches	50	8		Wind	D, S		40	75.00
A. A. Smith	32	14	21	1890	Bored, 2 inches		12		Steam	D			
H. M. Eddy	33	14	21	1887	do	65	9		Hand	D, S		65	25.00
Lone Star school district	22	14	21	1897	do	60	12		do	D, S		24	4.00
M. Wash	27	14	21		Bored, 5 inches		13		do	D, S			4.00
W. H. Martin	26	14	21	1890	Bored, 2 inches		14		Hand	D, S			3.25
Mrs. J. J. Owen	31	14	22	1898	Bored, 5 inches	48	13		Wind	D, S		26	
D. W. Butler	31	14	22	1898	do	60	11.5		Hand	D, S		23	3.25
S. A. Tyler	32	14	22	1900	Bored, 8 inches	75	15		Wind	D, S			
Siering Bros	13	14	21	1892	Bored, 5 inches	90	10		do	D, S		90	65.00
Charles Preuss	19	14	22	1892	do	38	12		Hand	D, S		19	
W. H. Spitler	22	14	22		do	25	16		do	D, S			
W. R. Wilson	21	14	22		do		18		do	D, S			3.25
Will McKenzie	28	14	22		Bored, 2 inches	54	12		do	D, S			3.00
J. A. Roberts	3	15	22	1892	Bored, 6 inches	85	14		do	D, S			3.00
H. White	27	14	22	1892	Bored, 2 inches	32	10		do	D, S		4	3.50
S. W. Lewis	14	14	22	1898	Bored, 12 inches	48	18		Wind	D, S			
Mrs. J. D. Reese	9	14	23	1899	Dug	18	14		Hand	D, S			12.00
L. W. Hobler	14	14	23	1894	Bored, 2½ inches	14	10		do	D		10	
Jake Eppinger	26	14	23	1897	Bored, 6 inches	90	27		Wind	D, S			
Alta school district	30	14	24		Bored, 5 inches	100	20		Hand	D, S			4.25
Mrs. Merrit	29	14	24	1885	Bored, 6 inches	40	20		Wind	D, S			
Mr. Martínez	33	14	24	1886	Bored, 5 inches	97	12		Hand	D, S		97	3.25
Victor Franzen	12	15	23	1881	do	60	32		Wind	D, S			
Sacramento Bank	6	15	24		Bored, 7 inches	30	12		Hand	D, S			4.00
Gosliner Bros	7	15	24	1885	do	80	25		Wind	D, S		80	
German Loan & Savings Bank	13	15	23	1886	Bored, 5 inches	58	22		do	S			
A. L. Holmes	24	15	23		do	38	29		Hand	D, S			5.00
R. M. Wilson	19	15	24	1891	Bored, 7 inches	64	15		Wind	D, S			
California Flume & Lumber Co	29	15	24		Bored, 5 inches	50	13		Hand	D			3.50

TABLE 52.—*Records of wells in Fresno County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
L. Pederson	33	15	24	1900	Bored, 5 inches	75	12		Hand	D, S		$30	$3.50
Burris Bros	26	15	23		do	23	21		do	D, S			4.25
Joe Housley	27	15	23	1890	Bored, 6 inches	71	35		Wind	D			
Mr. Fisher	14	15	23		Bored, 5 inches	80	35		do	D, S			
Fink school district	10	15	23	1900	do	100	42		Hand	D, S			
J. H. Harden	15	15	23	1885	Bored, 6 inches	84	50		Wind	D, S		84	100.00
T. L. Reed	22	15	23	1889	Bored, 5 inches		60		Hand	D, S			
Southern Pacific Co	8	15	23		do		30		do	S			
Milton M. West	21	15	23	1891	do	45	40		do	D, S			
N. Boysen	20	15	23	1891	Bored, 8 inches	55	25		do	D, S			
J. M. Marshall	29	15	23	1881	Bored, 6 inches	116	30		Wind	D, S		116	42.00
M. E. Stanton	32	15	23	1888	Bored, 5 inches	62	40		do	D, S			
John Holnberg	33	15	23	1889	Bored, 6 inches	93	50		Hand	D, S			
G. Stromberg	4	16	23	1899	do	85	30		do	D, S		67	11.00
Heald & Helley	6	16	23	1897	Bored, 5 inches		14		do	D, S			12.00
G. Bordson	6	16	23	1888	do	40	14		Wind	D, S			200.00
Martin Miller	30	15	23	1880	do	70	20		do	D, S		70	46.00
Sacramento Bank	19	15	23	1885	do	53	30		Hand	D, S		53	11.00
C. O. Love	18	15	23	1885	Bored, 6 inches	30	25		do	D, S			5.00
E. L. Jediker	13	15	22	1884	Bored, 5 inches	59	25		Wind	D, S		59	158.00
Kimble estate	7	15	23		Bored, 6 inches	60	35		do	D, S			
H. O. Marshall	11	15	22		Bored, 5 inches		14		Hand	D, S			3.50
H. S. Hulbert	9	15	22	1879	do	72	10		Wind	D, S		79	200.00
A. J. Wells	9	15	22	1883	do	52	12		Hand	D, S		30	3.00
Shafer Bros	14	15	22	1886	do	70	16		do	S			3.50
G. L. Traber	26	15	22	1877	do	60	15		do	D, S			3.50
H. F. Graper	2	16	22	1888	Bored, 6 inches	48	13		do	D, S		36	3.50
	27	15	22		Bored		16.5		do	D, S			
D. C. McClarly	27	15	22	1881	Bored, 6 inches	65	15		do	D, S			3.25
F. P. Wall	22	15	22	1894	Bored, $1\frac{1}{2}$ inches	60	17		do	D, S			
Charles Woods	9	15	22	1885	Bored, 5 inches		13		do	D, S			4.00
A. T. Wilkinson	5	15	22	1889	Bored, $1\frac{1}{2}$ inches	30	18		Wind	D, S		15	40.00
A. D. Wilson	12	15	21		Bored, 5 inches		11		do	D, S			
F. Lemon	13	15	21		do		13		Hand	D, S			
T. M. Boyd	17	15	22	1881	do	60	13		do	D, S		60	11.00
George West & Son	29	15	22	1900	Bored, 8 inches	120	16		Steam	W	10	132	
Mrs. L. Vance	31	15	22	1885	Bored, 5 inches	75	15.5		Hand	D, S			3.25
C. T. Pierson	6	16	22	1890	Bored, 2 inches	80	12		do	D, S			2.25

S. Y. Gordon	7	16	22	1882	Bored, 5 inches	108	10		do	D, S		86	12.00
John H. Hoffman	1	16	21	1894	do	35	12		do	D, S		20	4.00
C. E. Roberts	1	16	21	1888	do	60	14		do	D, S			3.50
Wm. Dosdon	24	15	21	1894	Bored, 2 inches	60	15		Wind	D, S		27	40.00
J. M. Pugh	11	15	21	1882	Bored, 5 inches	42	12		do	D		26	14.00
Wylie M. Giffen	2	15	21		do		12.5		Hand	D, S			5.00
H. A. Ross	2	15	21	1898	do	60	12		do	D, S		45	4.00
R. E. Oliver	3	15	21	1899	do	29	16		do	D, S		21	4.00
A. R. Brown	10	15	21	1900	do	54	12		Wind	D, S		30	
W. R. Shannon	14	15	21	1890	do	52	11		Hand	D, S		26	11.00
Lem Lhung	15	15	21	1899	Bored	90	15		Wind	D			
A. Harris	23	15	21	1881	Bored, 5 inches	+100	14		Hand	D, S		75	11.00
J. C. Long	28	15	21	1892	Bored	80	12		Wind	D, S		60	100.00
Mrs. C. E. Gower	27	15	21	1894	Bored, 5 inches	85	14		do	D, S		75	
M. Leeper	34	15	21	1887	Bored, 2 inches	60	14		do	D		40	117.50
W. J. Zimmerman	34	15	21	1899	Bored, 6 inches	28	12		Hand	D, S		17	3.25
Fresno Loan & Savings Bank	34	15	21	1888	Bored, 5 inches	+100	12		do	D, S			3.25
J. B. Galbreath	28	15	21		Bored, 6 inches		14		Wind	D, S			
T. E. Finerty	4	16	21	1885	Bored, 5 inches	80	16		do	D, S		80	4.25
H. C. Hinkle	11	16	21	1890	do	40	8			D, S			
H. Craben	9	16	21	1894	do	50	14		Hand	D, S		25	3.25
Robert E. Hall	4	16	21	1890	do	100	14		Wind	D, S			49.00
Mr. Madden	29	15	21	1885	do	100	12		do	D, S			70.00
John K. Kennedy	30	15	21	1894	do	96	13		Hand	D, S		57	3.25
W. A. Mills	16	15	21	1900	do	48	14		do	D, S		30	4.00
S. U. Goree	8	15	21	1891	Bored, 4 inches	60	10		do	D, S		24	4.00
J. V. Lamore	18	15	21	1885	Bored, 2 inches	60	12		do	D, S		25	3.25
Chas. K. Kirby	18	15	21	1882	Bored, 5 inches		12		Wind	D, S			
J. F. Ward	12	15	20	1888	Bored, 2 inches	90	8		Hand	D, S		36	4.00
J. B. Perrin	12	15	20	1882	Bored, 5 inches	22	13		Wind	D, S		45	45.00
A. Buckland	11	15	20	1881	do	51	8		Hand	D, S		46	4.00
Phillip Koekler	26	15	20	1897	Bored, 2 inches	60	12		do	D, S		25	
Harland & Stevens	31	15	21	1885	Bored, 5 inches		14		do	D, S			4.00
E. R. Haycroft	6	16	21		Bored, 6 inches	50	12		do	D, S		62	4.00
C. M. Rasmussen	6	16	21	1885			12		do	D, S			4.00
C. Nelson	26	15	20		Bored, 2 inches	54	12		do	D, S		22	4.00
G. A. Pell	26	15	20	1890	do	60	12		Wind	D, S		24	47.00
Stevens & Harland	3	16	20		Bored, 5 inches	+ 50	15		do	D, S			
Do	3	15	20		do	+ 50	16		Hand	D, S			4.00
John Smith	21	15	20	1890	Bored, 2 inches	35	10		do	D, S		15	6.00
Mr. Dickerson	9	15	20	1885	do		10		do	D, S			4.00
N. M. Nelson	10	15	20		do	75	10		do	D, S			4.00
Geo. B. Rowell	3	15	20	1881	Bored, 8 inches	94	10		Wind	D, S		94	
J. Gowanlock	8	15	20	1890	Bored, 2 inches	60	10		Hand	D, S		25	4.00
D. W. Smith	31	15	20	1887	Bored, 7 inches	80	12		Gas			100	
A. B. Trautwein	6	16	20	1891	Bored, 2 inches	150	12		Wind	D, S			35.00
Louis Montego	1	16	19		Bored, 5 inches	+50	17			D, S			
S. F. Bank	36	15	19		Bored, 6 inches	36	10						
John Rottger	13	16	19		Bored, 3 inches		8		Hand	D, S			4.00
A. Christian	10	15	19	1890	Bored, 2 inches	100	9		Wind	D, S		40	95.00
J. W. Creelman	10	15	19	1890	Bored, 6 inches		10		Hand	D, S			
Geo. Keslang	14	15	19	1891	Bored, 2 inches	65	10		do	D, S		25	4.00

TABLE 52.—*Records of wells in Fresno County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
San Francisco Bank	7	16	20	1888	Bored, 7 inches	+30	20		Wind	D			
G. Kowser	20	16	20		Bored, 5 inches	42	17		Hand	D, S			$5.00
Captain Cuttle	36	16	19	1880	Bored	75	14		Wind	D, S			
Mrs. H. Worswick	1	17	19	1890	Bored, 6 inches	68	10		Hand	D, S		$50	4.00
Mrs. M. J. Hatch	34	16	19	1890	Bored, 5 inches	48	15		Wind	D			
Fred Eaton	34	16	19	1892	do	72	15		do	D, S		51	
Mrs. W. Jenkins	34	16	19	1886	Bored	130	14		Hand	D, S			4.00
Elkhorn school district	10	17	19	1896	Bored, 6 inches	100	9		do	D			
Louis Gobbi	13	17	19	1892	Bored, 6 inches	22	7		do	D, S		5	4.00
John Walker	7	17	20	1880	Bored, 8 inches	75	8		do	D			25.00
Elisha Harlon	18	17	20	1890	Bored, 7 inches	70	8		Wind	D		70	140.00
Fred Coleman	8	17	20	1893	Bored, 6 inches	27	7		do	D, S		23	
Lewis Gibbons	6	17	20	1880	Bored, 5 inches	118	10		do	D, S		95	45.00
Loan and Savings Bank	4	17	20	1886	Bored, 6 inches	104	10		Hand	D			10.00
Chas. S. Pierce	31	16	20	1890	do	45	12		Wind	D, S		45	
David Crawford	33	16	20	1887	do	80	18		do	D, S		65	14.00
Mr. White	16	16	20		do	24	16		Hand	D, S			4.00
Wm. Gibson	24	16	20	1880	do	26	12		do	D		26	4.00
J. H. Hudson	25	16	20	1880	Bored, 5 inches	60	12		do	D			4.00
Wm. Gibson	31	16	21		do		10		Wind	S			
J. G. Burnett	30	16	21	1890	Bored, 4 inches	25	7		Hand	D			4.00
David Heishie	20	16	21	1888	Bored, 5 inches		8.5		do	D			
Sacramento Bank	18	16	21	1890	Bored, 6 inches	30	10		do	D, S			3.25
Harry Weher	18	16	21		Dug, 1½ feet	12	10		do	D, S			3.25
Mr. Johnson	10	16	21		Bored, 5 inches		10		do	D, S			3.00
John Reynolds	14	16	21	1892	do	60	9		do	D, S			3.25
J. Hamilton	24	16	21	1899	Dug, 2 feet	22	10		do	D, S		10	3.25
Dick Butler	22	16	21	1888	Bored, 5 inches	30	11		Wind	D, S			4.00
E. R. Holton	28	16	21	1882	do	30	7		Hand	D, S			
Lee Burton	28	16	21	1880	Bored, 4 inches	70	10		do	D, S		40	3.00
Martin Elder	35	16	21	1898	Bored, 8 inches	52	8		Steam	I	25	52	436.00
T. J. Martin	26	16	21	1899	Bored, 10 inches	50	8		do	I	25	42	436.00
Will Pickard	36	16	21	1892	Bored, 5 inches		10		Hand	D, S			3.00
C. S. Campbell	24	16	21	1882	do	60	9		Wind	D, S			
Sacramento Bank	12	16	21	1880	do	75	12		Hand	D, S			3.50
Mrs. C. A. Hammer	18	16	22	1898	do	40	12		do	D, S		40	12.00
S. J. Pelton	19	16	22	1888	do	86	10		do	D, S			

J. C. Bell	29	16	22	1880	do	54	9		Wind	S		50	
W. W. Ryce	36	16	21	1886	do	106	10		Hand	D, S		36	4.00
Sacramento Bank	32	16	22	1875	do	35	10		do	D, S		35	4.00
Do	4	17	22	1875	do	50	10		do	D			4.00
Larse Anderson	21	16	22	1888	do	60	21		do	D, S		30	4.00
C. H. Van Horn	28	16	22	1896	do	82	12		Wind	D, S		41	
Cemetery	27	16	22		do		13		do	I			
W. T. Prather	17	16	22	1880	Bored, 6 inches		15		do	D, S			58.00
D. Patton	9	16	22	1880	Bored, 5 inches	100	11		Hand	D, S			
T. C. Clayton	3	16	22	1893	do	102	15		do	D		51	
A. J. Allen	10	16	22	1870	do	90	16		Wind	D, S		90	60.00
Helge Lee	14	16	22	1896	do		13		Hand	D, S			3.50
Chas. Strid	23	16	22	1892	do	30	12		do	D, S		22	3.50
W. H. Seward	13	16	22	1893	do	45	15		do	D, S		35	15.00
Frank Hanson	32	16	22	1889	do	40	15		do	D, S		30	3.50
N. J. Shadle	18	16	23	1891	do	60	20		do	D, S		44	
N. J. Layton	8	16	23	1884	do	64	20		Wind, hand	D, S			
F. C. Stillman	5	17	16	1892	Bored, 7 inches	160	77		Horse	I, S, B		300	

TULARE COUNTY.

GENERAL CONDITIONS.

Tulare County, lying north of Kern and east of Kings, includes the eastern edge of the large central artesian basin at its widest part, all of the delta of Kaweah and Tule rivers and a part of that of Kings River, and the famous citrus region of the foothills and the higher parts of the valley floor about Portersville, Exeter, and Lindsay. It also includes, in the southwestern corner, a part of the old bed of Tulare Lake and a part of the district submerged during the last extremely high water, in 1880. The high water of 1905–1907 did not quite reach the Tulare County line.

Kings, Kaweah, and Tule rivers are the chief sources of such additions to the ground waters as are made in this county, as they are the sources of the surface waters used by the various canal systems.[1] Each of these streams has a distinct though rather flat delta, and the attitude of the ground-water plane indicates that the stream channels and canals along the crests of the deltas are the direct sources of the ground waters in the higher portion of the valley within Tulare County, and that from these lines of supply the waters percolate toward the lower parts of the valley and toward the areas between the deltas. These interareas receive only the slight direct supply that is derived from rainfall and from the minor streams that drain the foothills.

Within the artesian basin south and west of Tulare the ground waters, although receiving local additions within the county, are a part of the general body of ground waters of the central valley, stored there as a result of accumulation from all sources during centuries past, and are in general slow in motion northward along the valley axis.

FLOWING WELLS.

In the 365 or 370 square miles of artesian-water land within the county there were about 125 flowing wells in 1905, representing an investment of between $150,000 and $200,000. Nearly 100 of these wells were used for irrigation, and the combined yield of all of them was estimated at less than 25 second-feet. The greater number of them are 7 inches or more in diameter, while a few old wells are of smaller bore. They are most numerous on the Kaweah delta west of Tulare and somewhat farther south, west of Tipton and Pixley. Pasture lands, alfalfa, gardens, deciduous fruits, and vineyards are irrigated by the use of the waters developed.

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[1] An account of these systems was published in U. S. Geol. Survey Water-Supply Papers 17 and 18. These papers are out of print but may be consulted in libraries.

PUMPING PLANTS.

Irrigation by the use of pumped water is more extensively practiced in Tulare County than anywhere else in the valley. This is due to the development of citrus culture along the foothills between Tule River and Kaweah River, where methods in vogue in the citrus districts south of the Tehachapi have been introduced. There were in all about 170 pumping plants in use for irrigation in 1905, while a number of others were in use for domestic or town supplies. Of the total number 125 were electrically driven by power from one company and 45 were gas or steam plants.

These plants are adapted to a wide variety of conditions, some of them pumping from wells in which the water stands at the surface, and others lifting it from a depth of 100 feet. In the irrigation of some of the hillside citrus groves water is forced to heights of several hundred feet, usually from a reservoir into which it is pumped from the wells. The best equipped plants that overcome lifts of less than 75 or 80 feet use centrifugal pumps directly connected with motors; when the lifts are greater some form of deep-well plunger pump is used.

In the Lindsay district the ground-water level varies greatly each year, falling during the pumping season and rising again in the winter and spring. To keep the pumps and motors within the suction limit during the low-water period, and at the same time to prevent their submersion during the winter season, some of the ranchers have adopted the plan of placing the machinery in a tank. In one plant examined, the motor and pump were fastened to a movable platform that could be raised or lowered in adjustment to the varying ground-water level.

The Badger Irrigation Co. at Exeter has a particularly interesting plant because of the high lift of waters for irrigation. A description of this plant is given in the chapter on pumping tests.

PERMANENCE OF THE GROUND-WATER SUPPLY.

Most artesian basins are very sensitive to development, old wells decreasing in yield as new ones are installed, the shallow wells and those about the upper, outer edge of the basin being the first to show signs of failure. Diminution in the flow of the less favorably situated wells will take place in actual practice long before the basin is overtaxed, hence some alarm is likely to be felt and some individual loss may occur before the alarm is justified by general conditions. In addition to the normal diminution of flow in wells due to physical deterioration in casing or to other causes not related to a general loss of head and reduction in supply, a new well drilled in the neighborhood of an old one, or so situated as to draw in part from the same

general zone of saturated porous materials, will affect the yield of the first, although the combined yields of the two are much greater than that of either alone and much less than the supply.

Until wells are withdrawing water from an area more rapidly than it is supplied, even though there may be reduction in the yield of individual wells, there is no cause for alarm. It is difficult to determine when this point is reached in an artesian basin because diminution in flowing wells begins soon after development has begun, but when waters are pumped it is less difficult to tell. The continued lowering of the ground-water level in a pumped well, through years of average or abundant rainfall, with gradually increasing lifts and correspondingly increasing costs, indicates overuse.

A comparison of the flows of a number of artesian wells in Tulare County, measured first by the California State Engineering Department in 1885, and 20 years later by the United States Geological Survey, indicates, as is to be expected, a general diminution of yield, this decrease varying from 40 to 90 per cent. A part of it is undoubtedly due to the installation of new wells in recent years, but much of it is to be accounted for by the clogging and filling of the wells and the rusting of the casing. In any event the losses are not serious, and in view of the immensity of the basin and the large supplies that reach it annually, it can not be considered to have approached the point of overuse.

This observation, however, does not hold for some of the areas in which pumping is most intense. The lands favorable for citrus culture are distributed along a frost-free belt on the lower foothills and adjacent high parts of the valley floor. The zone of most intense pumping is along the eastern edge of the valley, between the deltas of Tule and Kaweah rivers. The ground waters here receive some slight accessions from local run-off from the foothills and from minor streams that flow out from them, but their principal source is the constant supply that sinks in the deltas of the major streams and percolates thence slowly in all directions.

On the deltas themselves, especially along their lower portions, where so much damage has been done in recent years as a result of over-irrigation, the consequent rise of the ground-water plane and with it the alkali, pumping is most helpful; in fact, pumping will doubtless be one of the means by which the damage done by over-irrigation in the past will be remedied in the future; but in the citrus belt of Tulare County pumping thus far has been concentrated upon those points remote from the deltas and from the trough of the valley, where supplies are least rapidly replenished. As a result there has been a noticeable lowering of the water plane in recent years and an increased cost of the water product. As a matter of safety to the orchards already producing, means should be taken to prevent the

E. Renard	140	...do	...do	...do	Do.
Do	70	...do	...do	...do	Do.
C. H. Slaughter	60	...do	...do	...do	Do.
J. J. Mull	35	Low	Na-CO_3	Good	Do.
J. H. Hauschildt	11	Moderate	...do	Fair	Fair.
Laurel school district	45	...do	Ca-CO_3	...do	Good.
W. A. Bedford	20	...do	Na-CO_3	...do	Do.
F. J. Hesse	20	Low	...do	Good	Do.
Mrs. C. Ranger	15	Moderate	...do	...do	Fair.
Pacific Coast Oil Co	25	Low	...do	...do	Good.
J. H. Glide	30	Moderate	Ca-CO_3	Poor	Do.
Cutler Bros	35	...do	...do	Fair	Do.
Frank Siseler	35	...do	...do	Poor	Do.
C. M. Midder	25	...do	...do	...do	Do.
M. F. Capell	12	...do	Na-CO_3	Fair	Fair.
W. L. Thomas	16	...do	...do	...do	Do.
A. L. Simmons	35	...do	...do	...do	Good.
A. Swanson	80	...do	Ca-CO_3	...do	Do.
	4.4	High	Na-Cl	Very bad	Poor.
S. J. Vincent	40	Moderate	Ca-CO_3	Poor	Good.
Mr. Leavitt	30	...do	...do	Fair	Do.
H. E. Redman	100	...do	...do	...do	Do.
City of Portersville	70	...do	...do	...do	Do.

Owner.	Classification. Chemical character.	Quality for boilers.	Quality for irrigation.	Analyst.
H. A. Burke	Ca-Cl	Bad	Fair	F. M. Eaton.
Southern Pacific Co	Na-CO_3	Good	Good	Southern Pacific Co.
Do	Ca-CO_3	Fair	...do	Do.
J. H. Hauschildt	Na-CO_3	Good	Fair	F. M. Eaton.
Tulare Water Co	...do	...do	Good	Southern Pacific Co.
Do	Ca-CO_3	Fair	...do	F. M. Eaton.
Santa Fe Ry. Co	...do	...do	...do	Kennicott Water Softener Co.
Southern Pacific Co	...do	...do	...do	Southern Pacific Co.
Do	...do	...do	...do	Do.
Exeter Waterworks	...do	...do	...do	Do.
Mrs. S. Navarre	...do	...do	...do	F. M. Eaton.
F. Stone	...do	...do	...do	Do.
G. K. Hostetter	...do	...do	...do	Do.
Southern Pacific Co	...do	...do	...do	Southern Pacific Co.

0 foot wells.

TABLE 53.—*Field assays of ground waters in Tulare County.*

[Parts per million[a] except as otherwise designated.]

Owner.	Date, 1910.	Location. Sec.	T.	R.	Depth of well (feet).	Determined quantities. Carbonate radicle (CO_3).	Bicarbonate radicle HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Computed quantities. Total solids.	Scale-foaming ingredients (s).	Foaming ingredients (f).	Probability of corrosion[a] (c).	Alkali coefficient (k) (inches).	Classification. Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.
D. H. Dopkins	Nov. 18	11	16 S.	23 E.	46	0	103	Tr.	70	158	250	210	40	?	30	Moderate	$Ca-CO_3$	Fair	Good.
C. F. Gustaveson	...do	21	16 S.	23 E.	120	0	127	Tr.	25	137	200	190	10	?	80	...do	...do	...do	Do.
Augustus Bell	...do	31	16 S.	23 E.	48	12	100	Tr.	35	135	210	180	20	?	60	...do	...do	...do	Do.
Kennedy school district	...do	34	16 S.	23 E.	40	Tr.	162	Tr.	35	138	250	190	60	N. C.	60	...do	...do	...do	Do.
George Clark	Nov. 17	2	18 S.	23 E.	42	0	208	202	490	425	1,300	160	880	?	4	High	Na-Cl	Very bad	Poor.
J. Kamo	...do	14	18 S.	23 E.	35	0	147	Tr.	25	93	220	140	80	N. C.	30	Moderate	$Ca-CO_3$	Fair	Good.
James Brady	...do	2	19 S.	23 E.	13	0	170	Tr.	10	101	210	150	70	N. C.	30	...do	...do	...do	Do.
John Habesy	Nov. 15	1	20 S.	23 E.	600	15	64	Tr.	15	10	160	60	120	N. C.	16	...do	$Na-CO_3$	Good	Fair.
J. F. Chism	Nov. 22	25	20 S.	23 E.	60	0	127	Tr.	10	88	180	140	40	N. C.	55	...do	$Ca-CO_3$	Fair	Good.
L. M. Coke	...do	25	20 S.	23 E.	640	12	102	Tr.	45	30	230	80	190	N. C.	12	...do	$Na-CO_3$	...do	Fair.
S. S. Hough	...do	32	20 S.	23 E.	75	0	161	Tr.	10	117	200	170	40	N. C.	55	...do	$Ca-CO_3$	...do	Good.
Wallace Bros	...do	32	20 S.	23 E.	530	15	80	Tr.	15	4	170	50	150	N. C.	13	...do	$Na-CO_3$	Good	Fair.
Waukena Development Co	...do	32	20 S.	23 E.	808	9	91	Tr.	15	16	170	60	130	N. C.	15	...do	...do	...do	Do.
C. H. Carlton	Nov. 23	16	22 S.	23 E.	30	Tr.	155	20	30	38	260	90	200	N. C.	12	...do	...do	Fair	Do.
W. S. Miller	Nov. 25	24	22 S.	23 E.	63	0	143	Tr.	15	76	200	130	80	N. C.	26	...do	$Ca-CO_3$	...do	Good.
H. W. Butcher	Nov. 23	27	22 S.	23 E.	50	0	98	5	15	30	160	80	110	N. C.	20	...do	$Na-CO_3$	Oood	Do.
Do	...do	27	22 S.	23 E.	360	6	120	Tr.	10	37	180	90	120	N. C.	16	...do	...do	...do	Fair.
P. D. Brubaker	Nov. 24	3	23 S.	23 E.	355	12	93	Tr.	15	20	180	70	130	N. C.	15	...do	...do	...do	Do.
Do	...do	3	23 S.	23 E.	1,025	6	95	Tr.	15	32	170	80	110	N. C.	20	...do	...do	...do	Good.
W. H. Wilbur	Nov. 25	33	23 S.	23 E.	1,180	6	133	Tr.	10	27	190	80	150	N. C.	13	...do	...do	...do	Fair.
City of Alpaugh	...do	33	23 S.	23 E.	2,000	Tr.	266	5	180	154	560	180	430	N. C.	11	High	Na-Cl	Bad	Do.
C. A. Canfield	...do	3	24 S.	23 E.	750	12	129	Tr.	10	20	200	70	160	N. C.	12	Moderate	$Na-CO_3$	Good	Do.
M. Kline	...do	7	24 S.	23 E.	650	9	160	Tr.	5	25	210	80	160	N. C.	11	...do	...do	...ao	Do.
T. W. Carr	Nov. 18	7	16 S.	24 E.	88	0	82	Tr.	10	24	140	70	80	N. C.	25	Low	...do	...do	Good.
City of Dinuba	...do	17	16 S.	24 E.	278	0	164	Tr.	40	148	260	200	60	N. C.	50	Moderate	$Ca-CO_3$	Fair	Do.
E. H. Granz	...do	22	16 S.	24 E.	89	0	168	Tr.	25	132	230	180	50	N. C.	55	...do	...do	...do	Do.
Bank of Visalia	Nov. 17	30	18 S.	24 E.	800	9	103	Tr.	15	19	180	70	130	N. C.	15	...do	$Na-CO_3$	Good	Fair.
Alta Comstock	...do	4	19 S.	24 E.	45	0	123	Tr.	15	87	180	140	50	N. C.	55	...do	$Ca-CO_3$	Fair	Good.
Packwood school district	...do	6	19 S.	24 E.	40	Tr.	144	Tr.	15	105	200	150	50	N. C.	50	...do	...do	...do	Do.
I. D. Reinhardt	...do	20	19 S.	24 E.	24	0	132	Tr.	10	92	180	140	40	N. C.	55	...do	...do	...do	Do.
E. Renard	...do	22	19 S.	24 E.	85	0	123	Tr.	15	100	180	150	30	N. C.	140	...do	...do	...do	Do.
Do	...do	22	19 S.	24 E.	135	0	104	Tr.	15	78	160	130	40	N. C.	70	...do	...do	...do	Do.
C. H. Slaughter	Nov. 15	4	20 S.	24 E.	60	0	107	Tr.	10	74	160	120	30	N. C.	60	...do	...do	...do	Do.
J. J. Mull	...do	5	20 S.	24 E.	316	12	48	Tr.	5	27	120	80	50	N. C.	35	Low	$Na-CO_3$	Good	Do.
J. H. Hauschildt	Nov. 17	5	20 S.	24 E.	850	12	103	Tr.	25	3	200	55	190	N. C.	11	Moderate	...do	Fair	Fair.
Laurel school district	Nov. 15	6	20 S.	24 E	46	0	119	Tr.	5	71	160	120	40	N. C.	45	...do	$Ca-CO_3$	...do	Good.
W. A. Bedford	Nov. 16	19	20 S.	24 E.	78	0	156	Tr.	10	72	200	120	90	N. C.	20	...do	$Na-CO_3$	...do	Do.
F. J. Hesse	Nov. 25	20	22 S.	24 E.	606	18	47	5	15	15	150	60	110	N. C.	20	Low	...do	Good	Do.
Mrs. C. Ranger	...do	22	22 S.	24 E.	1,400	18	68	5	15	8	170	60	130	N. C.	15	Moderate	...do	...do	Fair.
Pacific Coast Oil Co	Nov. 24	19	23 S.	24 E.	726	0	83	Tr.	5	18	130	70	80	N. C.	25	Low	...do	...do	Good.
J. H. Glide	Nov. 18	31	16 S.	25 E.	39	0	192	10	70	273	310	320	0	?	30	Moderate	$Ca-CO_3$	Poor	Do.
Cutler Bros	Nov. 19	5	17 S.	25 E.	35	0	208	Tr.	20	144	260	190	70	N. C.	35	...do	...do	Fair	Do.
Frank Sisefer	...do	32	17 S.	25 E.	65	0	170	5	55	195	290	250	40	?	35	...do	...do	Poor	Do.
C. M. Midder	Nov. 21	4	20 S.	25 E.	52	0	242	15	75	300	400	330	30	?	25	...do	...do	...do	Do.
M. F. Capell	Nov. 25	6	23 S.	25 E.	20	0	227	15	45	113	340	160	200	N. C.	12	...do	$Na-CO_3$	Fair	Fair.
W. L. Thomas	Nov. 26	34	23 S.	25 E.	28	0	158	10	30	75	250	120	150	N. C.	16	...do	...do	...do	Do.
A. L. Simmons	...do	4	21 S.	25 E.	160	0	110	Tr.	15	65	170	120	70	N. C.	35	...do	...do	...do	Good.
A. Swanson	Nov. 21	3	20 S.	26 E.	40	0	172	6	25	152	240	200	40	N. C.	80	...do	$Ca-CO_3$	...do	Do.
	...do	8	20 S.	26 E.	40	0	273	136	435	277	1,200	310	950	?	4.4	High	Na-Cl	Very bad	Poor.
S. J. Vincent	...do	27	21 S.	26 E.	75	0	174	15	55	244	310	290	0	?	40	Moderate	$Ca-CO_3$	Poor	Good.
Mr. Leavitt	...do	35	21 S.	26 E.	170	0	167	Tr.	15	106	220	160	70	N. C.	30	...do	...do	Fair	Do.
H. E. Redman	...do	6	20 S.	27 E.	185	Tr.	159	5	20	136	230	190	40	N. C.	100	...do	...do	...do	Do.
City of Portersville	...do	25	21 S.	27 E.	200	0	200	Tr.	20	160	250	210	40	N. C.	70	...do	...do	...do	Do.

[a] C., corrosive; N. C., noncorrosive; ?, corrosion uncertain or doubtful.

TABLE 54.—*Mineral analyses of ground waters in Tulare County.*

[Parts per million except as otherwise designated.]

Owner.	Date.	Location. Sec.	T.	R.	Depth of well (feet).	Determined quantities. Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Computed quantities. Scale-forming ingredients (s).	Foaming ingredients (f).	Probability of corrosion (c).	Alkali coefficient (k) (inches).	Classification. Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.	Analyst.
H. A. Burke	Nov. 18, 1910	16	17 S.	23 E.	60	......	0.25	131	54	[a]58	0	181	48	337	902	530	150	C.	6.0	High	Ca-Cl	Bad	Fair	F. M. Eaton.
Southern Pacific Co	Mar. 28, 1902	24	18 S.	23 E.	250	[b]26	......	11	1	30	0	86	8	10	129	60	80	N. C.	30	Low	$Na-CO_3$	Good	Good	Southern Pacific Co.
Do	Aug. 4, 1902	17	16 S.	24 E.	85	[b]60	......	38	10	29	0	168	7	40	267	190	80	N. C.	50	Moderate	$Ca-CO_3$	Fair	...do	Do.
J. H. Hauschildt	Nov. 17, 1910	5	20 S.	24 E.	850	......	.35	5.0	1.5	[a]67	23	85	4.1	22	202	65	150	N. C.	14	...do	$Na-CO_3$	Good	Fair	F. M. Eaton.
Tulare Water Co	Apr. 2, 1902	10	20 S.	24 E.	(c)	[b]16	......	14	1	24	0	90	3	8	111	60	65	N. C.	30	Low	...do	...do	Good	Southern Pacific Co.
Do	Nov. 14, 1910	10	20 S.	24 E.	800	......	.25	29	4.0	[a]18	0	122	14	9.0	174	140	50	N. C.	75	Moderate	$Ca-CO_3$	Fair	...do	F. M. Eaton.
Santa Fe Ry. Co	Nov. 4, 1902	29	18 S.	25 E.	......	[b]26	......	26	6	[a]8	0	102	5	12	134	115	20	N. C.	170	Low	...do	...do	...do	Kennicott Water Softener Co.
Southern Pacific Co	May 30, 1902	31	21 S.	25 E.	60	[b]24	......	37	3	26	0	172	7	11	193	140	70	N. C.	35	Moderate	...do	...do	...do	Southern Pacific Co.
Do	Aug. 1, 1910	31	21 S.	25 E.	65	[b]25	......	32	4	29	0	174	7	8	191	125	80	N. C.	30	...do	...do	...do	...do	Do.
Exeter Waterworks	Dec. 29, 1904	10	19 S.	26 E.	100	[b]39	......	26	9	32	0	144	11	27	215	130	85	N. C.	35	...do	...do	...do	...do	Do.
Mrs. S. Navarre	Nov. 21, 1910	2	20 S.	26 E.	60	......	.60	40	16	......	0	165	......	32	260	200	......	?	65	...do	...do	...do	...do	F. M. Eaton.
F. Stone	...do	10	21 S.	26 E.	50	......	.50	46	8.9	[a]28	0	218	12	15	242	200	75	N. C.	35	...do	...do	...do	...do	Do.
G. K. Hostetter	...do	6	20 S.	27 E.	(d)	......	.35	32	13	[a]14	0	157	14	15	258	170	40	N. C.	125	...do	...do	...do	...do	Do.
Southern Pacific Co	Jan. 6, 1902	35	21 S.	27 E.	31	[b]20	......	36	6	19	0	160	6	13	179	135	50	N. C.	55	...do	...do	...do	...do	Southern Pacific Co.

[a] Computed.
[b] Including oxides of iron and aluminum.
[c] Uncertain whether water is from 400 or 800 foot wells.
[d] Two wells 250 and 255 feet deep.

installation of additional pumping plants in those parts of the citrus belt where development is now most intense and the effects upon the ground water have been most clearly discerned, for it is obviously more important to protect the orchards that are already producing than to plant more.

QUALITY OF WATER.

The quality of ground water in the basin of Tulare Lake has been discussed in detail in pages 104–109. Waters from wells 20 to 1,400 feet deep east of the boundary indicated by B′B′ (Pl. II), generally are carbonate waters, good or fair for irrigation, containing about 240 parts per million of total solids. Nearly all the deep wells yield sodium carbonate water; nearly all the supplies are low in scale-forming and foaming ingredients and are noncorrosive. The waters from wells less than 100 feet deep show greater difference in quality than the deeper supplies, a condition explainable by the probability that the more highly mineralized ones come from pockets of alkali-impregnated silt. The shallow waters of high mineral content almost invariably are taken from wells on tracts showing alkali.

WELL RECORDS.

Detailed records of wells in Tulare County that have been examined are assembled in the following tables:

TABLE 55.—*Records of wells in Tulare County.*

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.[a]	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
G. W. Donnel	3	16	23		Bored, 6 inches	70	20	72	Wind	D, S			
J. Bollinger	3	16	23	1892	Bored, 5 inches	40	9	71	do	D			
J. O. Kieger	10	16	23	1893	Bored, 6 inches	60	13	68	Hand	D		$30	
Mrs. R. Duffy	16	16	23	1903	do	60	12	71	do	D			
D. H. Dopkins	11	16	23	1883	Bored, 7 inches	46	10	72	do	D		35	
W. P. Moore	13	16	23	1904	Bored, 5 inches	72	9	72	do	D, S		36	
F. Don	7	16	24	1901	do	75	8		do	D, S		40	
W. C. Lewis	7	16	24	1904	do	68	6	71	do	D		35	
W. Savateir	7	16	24	1904	do	72	8		do	D		35	
G. E. Carver	7	16	24	1904	do	64	6	72	do	D, S		30	
T. W. Carr	7	16	24	1902	do	88	7		Wind	D		48	
M. E. Hines	1	16	23		do	85	8	72	do	D, S		40	
J. B. Long	6	16	24	1904	do	30	7	71	Hand	S			
Wm. Anderson	5	16	24	1902	do	63	7		do	D		30	
G. Botts	5	16	24		Bored, 6 inches	64	8	71	do	D			
E. Finley	9	16	24		Bored, 5 inches	71	8	71	do	D			
W. E. Hawkins	9	16	24	1902	Bored, 6 inches	76	7	72	Wind	D, S		45	
W. A. Williams	9	16	24		do	86	11	72	do	D, S		50	
H. Jacobs	3	16	24		Bored, 5 inches	80	28	71	do	S		40	
B. F. Tout	11	16	24	1885	do	60	10	70	Hand	D		30	
A. McEdminston	11	16	24	1900	do	60	10	70	do	D		30	
T. Arthur	13	16	24	1901	do	39	11	72	do	D		20	
N. P. Edmunson	7	16	25	1902	Bored, 10 inches	76	11		Gas	I	46	65	
R. S. Demaree	5	16	25	1902	Bored, 12 inches	140	18		do			120	$600.00
Roy Stevens	5	16	25	1904	Bored, 10 inches	80	13		do	I		60	560.00
C. W. Steves	5	16	25	1905	do	75	13					49	
H. Bernhorn	8	16	25	1902	Bored, 6 inches	55	11	71	Hand	D		30	
J. H. Glide	9	16	25	1883	do	60	16	71	Wind	D, S		35?	
Do	10	16	25	1895	do	43	15	70	Hand	S			
M. W. Curtin	15	16	25	1885	do	61	15	71	Wind	S		30	
J. S. Boyd	22	16	25	1883	Bored, 5 inches	50	13	71	Hand	D, S		25	
M. S. Jerryman	28	16	25	1902	Bored, 10 inches	75	11	69	Gas	I	37	75	
J. J. Wheelock	27	16	25	1897	Bored, 7 inches	90	11	70	Steam	I		70	

G. W. Kirkman	20	16	25	1890	Bored, 6 inches	36	8	71	Hand	D, S			
T. R. Dennison	20	16	25		Bored, 5 inches	51	8	70	do	D			
A. W. Canfield	13	16	24	1889	do	48	8	70	do	D			
J. T. Ward	24	16	24	1901	Bored, 6 inches	67	8	70	do	D, S		35	
M. A. Haas	14	16	24	1887	Bored, 5 inches	51	8	71	do	D			
Dan Clubb	23	16	24	1903	Bored, 2 inches	65	8	71	do			35	
F. L. Allen	23	16	24	1900	Bored, 5 inches	50	7	71	Wind	D		25	
M. Lyall	23	16	24	1900	Bored, 6 inches	62	8	72	do	D			
A. H. Rohlfin	22	16	24		do	50	10	71		D, S			
C. J. Walker	28	16	24	1901	Bored, 7 inches	35	6	70	Hand	D			
Mrs. J. Vose	21	16	24	1900	Bored, 5 inches	60	6	72	do	D			
Sweet & Levis	28	16	24		Bored, 6 inches	90	6		Wind	S		70	
C. F. Gidding	21	16	24	1900	Bored, 5 inches	60	8	71	Hand	D		20	
A. Frazer	15	16	24	1896	Bored, 6 inches	73	7		Wind	D, S		35	
E. Moore	17	16	24		Bored, 5 inches	75	7	72	do	D, S		40	
L. Lindley	20	16	24		do	70	7	72	do	D, S			
W. I. Rice	19	16	24		do	39	6	70	Hand	D			
C. B. Funk	9	16	24	1904	do	85	7	72	do	D, S		45	
J. F. Miller	20	16	24	1901	Bored, 6 inches	62	7	71	Wind	S		30	
R. F. Dunn	29	16	24		Bored, 5 inches	48	9	71	Hand	D, S		25	
W. L. Heine	14	16	23		do	43	9	72	do	D		20	
A. Scrarone	24	16	23	1897	Bored, 6 inches	68	7		Wind	D, S		35	
R. Kennedy	24	16	23		Bored, 5 inches	36	9		do	S			
Do	26	16	23		Bored, 6 inches	58	10	72	do	D, S			
J. E. Anderson	27	16	23	1893	Bored, 5 inches	52	6	72	do	D, S		40	
W. F. Chrisman	22	16	23	1903	do	54	6	72	Hand	D		30	
G. V. Reed	22	16	23	1897	do		10	68	do	D		15	
J. H. Fox	28	16	23	1890	do	43	7		Wind	S			
M. G. Thompson	27	16	23	1892	do	47	7	72	do	D, S		25	
W. P. Boone	31	16	23	1897	do	48	5	71	do	S		25	
R. H. Fray	4	17	23	1895	Bored, 6 inches	50	5	71	Hand	D		25	
W. Hurse	4	17	23	1905	do	50	5	70	do	D		25	
F. M. Wasgett	23	16	23	1892	Bored, 5 inches	23	4	68	Horse		12	10	
J. A. Boyd	34	16	23	1888	Bored, 6 inches	50	6	70	Wind	D		25	
A. S. Brewer	2	17	23	1890	Bored, 5 inches	43	6	69	do	D, S		20	
D. H. Curtin	35	16	23		do	52	8	72	do	D, S		25	
A. K. Smith	35	16	23	1890	do	35	6	70	do	D, S		20	
Wm. Smith	35	16	23	1897	Bored, 6 inches	26	6	68	Hand	D		15	
California Savings & Loan Society	2	17	23	1890	Bored, 5 inches	30	6	69	do	D		15	
R. Kennedy	36	16	23	1901	Bored, 6 inches	36	5	71	Wind	S		18	
Mrs. E. J. Lovelace	31	16	24		do	50	6	68	Hand	D, S		25	
J. S. Cash	5	17	24	1903	Bored, 5 inches	57	6	70	do	D, S		30	
Mrs. M. Lewis	5	17	24		do	49	4	70	Wind	D, S			
S. K. Green	32	16	24	1889	do	51	4	70	do	D, S		33	
E. C. Tatum	28	16	24	1903	Bored, 6 inches	49	5		do	D, S		25	
S. Hicks	33	16	24	1902	Bored, 5 inches	60	5	69	Hand	D		39	
H. G. Swab	3	17	24	1904	Bored, 6 inches	50	5	70	do	D		25	
R. M. Lewis	34	16	24	1897	Bored, 5 inches	34	4	69	do	D, S		15	
J. W. Garr	34	16	24	1892	Bored, 6 inches	52	5	69	do	D			
S. A. Harris	2	17	24	1904	Bored, 5 inches	35	5	70	do	D		20	
R. J. Kirk	2	17	24	1895	Bored, 4 inches	45	4	67	do	D, S		20	

a D, domestic; S, stock; I, irrigation; B, boilers; N, not used.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location. Section.	Town-ship south.	Range east.	Year com-pleted.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of ma-chinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
H. W. Terrill	36	16	24	1902	Bored, 5 inches	60	5	70	Hand	D		$30	
J. H. Glide	31	16	25	1886	Bored, 6 inches	39	9	71	do	D		20	
J. M. Parker	32	16	25	1904	Bored, 2½ inches	65	5		Wind, hand	D, S			
Wm. Kalb	32	16	25	1903	do	60	7		Hand	D, S			
Jacob M. Hamlin	33	16	25	1905	Bored, 5 inches	70	10 12	70	do	D			
J. G. Hitchcock	3	17	25		Bored, 6 inches	14	7	69	do	D, S			
J. K. Yoakum	35	16	25		Bored, 5 inches	36	15	70	do	D		20	
San Francisco Savings Union	31	16	26		Bored, 6 inches	46	26	70	Wind	D		25	
F. Tessman	5	17	26		do	54	30	70	do	D		25	
Mrs. M. E. Harell	8	17	26		Bored, 5 inches	36	22	69	do	S		20	
Stone Corall school district	12	17	25		do	38	15	69	Hand	D			
Mrs. M. E. Harell	13	17	25		do	48	14	69	do	D, S		25	
J. E. Fentley	22	17	25	1903	Bored, 12 inches	63	11		Gas	I			
J. W. Summers	21	17	25	1884	do	30	8		do	D, S			$110.00
P. Banks	8	17	25	1886	Bored, 5 inches	48	6	68	Hand	D, S			
Cosmos Land & Water Co	29	17	25		Bored, 7 inches	70	12		do	S			
B. Depen	12	17	24	1890	Bored, 6 inches	32	7	69	do	S		15	
W. Sim	24	17	24	1890	Bored, 5 inches	40	6	68	Wind	D, S			
Mrs. E. McCaulley	24	17	24		do	41	6	69	Hand	S		20	
J. Mackin	23	17	24	1889	do	54	5	69	do	D		25	
Sacramento Bank	11	17	24	1902	Bored, 6 inches	44	6	71	Wind	S			
W. Vose	14	17	24	1895	Bored, 5 inches	32	5	68	do	S		15	45.00
D. S. Meyers	10	17	24		do	40	5	68	Hand	N			
H. Williams	15	17	24	1865	Bored, 10 inches	60	6	66	Not raised	N		1	
G. Langrick estate	21	17	24		Bored, 5 inches	30	6	68	Wind	S		15	
J. Harrel Rothmanage	27	17	24		Bored, 6 inches	54	6	66	Hand	D, S			
M. R. Davis	8	17	24		Bored, 5 inches	30	4	65	Wind	S			
A. Murray	18	17	24	1905	Bored	60	5	66	Hand	D		30	
J. A. Kimble	18	17	24		Bored, 6 inches	33	5	70	Wind	D, S		15	
J. A. Moreland	18	17	24		Bored, 5 inches	49	4	70	do	S			
S. Kerr	24	17	23	1902	do	32	4	70	Hand	D, S			
Moreland school district	7	17	23		do	41	4	66	do	D			
J. D. Vannoy	6	17	24	1890	do	56	4	66	Wind	D, S		30	
C. J. Archer	12	17	23		Bored, 6 inches	33	4	65	do	D, S		17	
H. E. Kellog	12	17	23		Bored, 5 inches	38	4	65	Hand	D			
C. W. Clarke	11	17	23		do	54	4	67	do	D			
L. Sproat	10	17	23	1885	do	47	4	67	do	D			

D. A. Boone	11	17	23	1888	Bored, 6 inches	60	4	69	Wind	D		30	
J. Harris	14	17	23	1889	Bored, 5 inches	56	4	68	do	D, S		30	
T. Musler	12	17	23		do	20	4	63	Hand	D		10	
J. A. Mobler	14	17	23	1887	Bored, 6 inches	40	5	71	Wind	D, S		20	
J. W. Alcorn	10	17	23	1886	Bored, 5 inches	29	4	66	Hand	D		15	
J. H. Garlish	10	17	23	1900	do	27	4	64	do	D		15	
Traver school district	16	17	23	1890	do	40	4	66	do	D		20	
H. Burke	16	17	23	1903	do	29	5	69	Wind	D		15	
J. Etzenhouser	9	17	23	1893	Bored, 6 inches	60		64	Hand	D		36	
A. T. Hines	8	17	23	1885	Bored, 5 inches	29	5	65	do	S			
G. Deedle	6	17	23	1890	do	25	7	66	do	D		15	
M. Rae	7	17	23	1902	do	33	5	68	do	D, S		15	
M. Rodgers	8	17	23		do	31	4	68	do	D			
J. H. Jacobs	17	17	23		do	30	4	69	do	S		15	
G. Ghemmelspach	21	17	23	1889		16	4	68	do	D			
A. A. Himrat	20	17	23	1882	Bored, 6 inches	42	5	71	do	D, S			
C. E. Barlow	30	17	23	1803	Bored, 5 inches	30	7	72	do	D, S			
C. A. Wood	22	17	23	1885	Bored, 6 inches	31	4	71	do	D, S		15	
N. Stobie	4	18	24	1900	Bored, 7 inches	60	7	67	Horse	D, S			
H. C. Hartley	25	17	24	1891	Bored, 5 inches	58	5	68	Wind	S		30	
Do	36	17	24		Bored, 7 inches		6	65	Wind, hand	D			
J. Rush	31	17	25		do	55	5	67	do	S			
J. G. Hicks	28	17	25	1890	do	37	9	69	Wind	D, S		40	100.00
R. L. March	28	17	25	1885	Bored, 5 inches	40	8	69	do	S			
W. H. Keener	34	17	25	1888	do		6	69	Wind, hand	D, S			
S. Palmer	2	18	25	1887	do	75	15	70	Wind	D, S			
Ivanhoe school district	6	18	26		Bored, 5 inches	40	14	71	Hand	D			
San Francisco Savings Union	5	18	26		do	41	20	68	do	D		20	
J. S. Cox	33	17	26	1900	Bored, 6 inches	23	11	66	do	D			
	34	17	26	1900	do	33	11	64	do	D, S		20	
J. B. Agnew	34	17	26	1880	Bored, 5 inches	25	25		do	D			
Red Banks Orchard Co.[a]	27	17	26	1903	Bored, 8 inches	60	30	71	Electric	I	23		
H. H. Brown	32	17	27	1903	Bored, 12 inches	100		73	do	I	[b] 15		
Antelope Heights Water & Irrigation Co	34	17	27	1905	(c)	35	5		Steam	I			
Pogue Bros	11	18	27	1895	Dug	14	5?		Electric	D			
E. E. Fitch	5	18	26	1894	Bored, 5 inches	52	19	65	Hand	D		25	
R. C. Hardin	1	18	25	1890	do	30	16	66	Wind	S			
E. M. Striler	1	18	25		Dug	15	12	63	Hand	D			
S. G. Uram	12	18	25		Bored, 5 inches	37	12	65	do	D			
C. Fray	12	18	25	1892	do	52	10	65	do	D		25	
L. G. Dickinson	13	18	25	1900	do	35	11	61	do	D		20	
T. F. Johnson	2	18	25	1893	Bored, 6 inches	28	6	70	Wind	D, S		15	
J. G. Hicks	3	18	25	1890	Bored, 5 inches	24	6	71	Hand	D		10	
C. Thomas	10	18	25	1885	do	30	5	66	do	D			
S. T. Allen	9	18	25		do	18	8	69	Wind	S			
Sam Ellis	4	18	25	1892	do	60	5		do	D, I			
B. F. Kibler	16	18	25		do	40	5	66	Hand	D			
T. J. Patterson	17	18	25		do	15	4		Wind	D			
Mrs. G. Chrisman	9	18	25	1900	do	42	4	67	Hand	D			
J. Watt	8	18	25		do	30	4	67	do	D, S			
Morgan Rush	8	18	25		do	26	6	67	do	D			

[a] Two wells.

[b] Yield estimated or statement of owner taken.

[c] Two dug wells and three 12-inch bored wells.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
Mrs. N. C. Smith	6	18	25	1890	Bored, 10 inches	60	6	66	Wind	D, S			
Howe & Trout	8	18	25	1890	Bored, 6 inches	35	7		Wind, hand	D, I, S			
Seth Smith, jr	7	18	25	1891	Bored, 5 inches		5	64	Wind	D, S			
J. A. Demarer	12	18	24	1886	do	33	3	64	Hand	D			
Cuthbert Burrel estate	12	18	24		Bored, 7 inches	20	2.5		Not raised	N			
A. C. Collier	10	18	24	1903	Bored, 5 inches	62	7	68	Horse	D, S		$32	$25.00
Mr. Crane	12	18	23		do	35	7	69	Wind	D, S			
C. W. Clark	2	18	23	1880	do	42	9	69	Hand	D, S		20	
J. Kame	14	18	23	1880	do	35	9	68	Wind	D, S		15	
Mrs. Codiga	22	18	23		do	38	11	70	do	D, S		20	
W. W. Worthing	22	18	23	1887	do	55	12	70	do	D, S		30	
R. Chatten	26	18	23		do	39	12	71	Hand	S			
E. H. Bock	23	18	23	1897	Bored, 12 inches	50	12		Gas	I	a 122	50	900.00
Edward Landigan	13	18	23	1882	Bored, 6 inches	52	8	70	Hand	D, S		26	4.00
Peter Mallock	18	18	24	1904	Bored, 5 inches	30	20?		Wind	S		15	50.00
Southern Pacific Co	19	18	24		Bored, 8 inches		16?		Steam	B	7		
Bank of Visalia	30	18	24		do	800	0	78	Artesian	I	a 1		
Montgomery estate	29	18	24		Bored, 7 inches	24	10	70	Wind	D, S		20	50.00
Timothy Hayes	17	18	24	1900	Bored, 5 inches	50	12	70	do	D, S		25	25.00
H. S. and H. G. Montgomery	16	18	24		Bored, 8 inches		9	67	Hand	S			4.00
Anna and H. Montgomery	22	18	24		do	33	5		do	S		25	4.00
Arthur Burton	28	18	24	1904	Bored, 6 inches	38	14?	68	do	D, S		19	4.00
G. D. Smith	23	18	24	1902	Bored, 5 inches	24	3	65	do	D, S		12	4.00
Ben Henry	23	18	24	1884	do	60	12?	68	Wind, hand				50.00
T. J. Akers	22	18	24	1901	do	48	13?	65	Wind	D, S		25	50.00
J. B. Jordan	15	18	24	1904	Bored, 6 inches	45	10?	66	Wind, hand	D, S		30	75.00
Mrs. John Parr	23	18	24		do	40	4		Wind	S		20	50.00
J. M. Lasco	23	18	24	1889	Bored, 5 inches	60	4	67	Hand	D, S		35	4.00
C. T. Poole	14	18	24	1902	do	35	5	65	do	D			
Julia Wilcox	23	18	24		do	35	4	64	do	D			
L. Henry	24	18	24	1904	do	30	4	64	do	D			
A. J. Weston	17	18	25	1897	do	45	4		Wind, horse	D, I, S			
Visalia Land & Fruit Co	18	18	25	1905	Bored, 12 inches	95	5		Steam	I			
Togni Rancho	20	18	25	1894	Bored, 5 inches	50?	4	65	Hand	D			
Encina Fruit Co	19	18	25	1904	Bored, 10 inches	34	4	65	Electric	I	85		
J. Jerrett	30	18	25	1903	Bored, 5 inches	40	5	66	Hand	D			
T. J. Patterson et al	16	18	25	1903	do	42	4	64	do	D			
Ed Bowman	28	18	25		do	42	6	65	do	D			

T. L. Sharp	21	18	25	1885	do	40	8?	65	do	D, S			
S. C. Brown	27	18	25	1875	Bored, 6 inches	38	6	63	do				
R. E. Hyde	22	18	25		Bored, 7 inches	33	7	64	do	D			
J. W. Clark	23	18	25		Bored, 5 inches	30	6	64	do	S			
T. H. Frans	26	18	25	1895	do	60	6	61	do	D		30	
A. R. Cutter	23	18	25		do	40	7	64	do	D		20	
E. S. Beardsley	13	18	25	1895	Bored, 6 inches	48	9	62	do	D		25	
M. B. Harris	3	19	23	1904	Bored, 10 inches	42	14		Gas	I		65	937.00
James Brady	2	19	23	1902	Dug, 4 by 8 feet	13	12	69	Hand	D, S		10	4.00
W. L. and F. H. Coughran	1	19	23	1904	Bored, 13 inches	42	14		Gas	I		70	1,480.00
Joe Garcia	36	18	23	1895	Bored, 5 inches	45	8.5	70	Hand	D, S		25	4.00
J. W. Badders	31	18	24		Bored, 6 inches	60	12?	68	do	D, S		30	4.00
Sam Henderson	6	19	24	1875?	Bored, 5 inches	50	19?	67	Wind	D, S		25	50.00
Packwood school district	6	19	24		Bored, 4 inches	40	12		Hand	D		20	3.50
E. O. Miller	6	19	24	1903	Bored, 7 inches	45	11		Wind	S		35	50.00
C. Hausch	7	19	24	1899	Bored, 4 inches	36	15?	69	do	D, S		20	50.00
E. O. Miller	5	19	24	1901	Bored, 7 inches	48	11	67	do	S		35	50.00
Do	5	19	24	1903	do	40	11?		do	S		30	50.00
Alta Comstock	4	19	24		Bored, 5 inches	45	7	69	Hand	D, S		25	4.00
Geo. Peterson	28	18	24	1879?	do	48	4	67	do	D		25	4.00
Isaac Shirk	28	18	24	1890	do	60	10?	66	Gas	D, S, I		30	200.00
D. W. Demasters	34	18	24	1890?	Bored, 4 inches	55	2?	67	Hand	D, S		30	4.00
Wiley Coughlan	34	18	24	1900	Bored, 6 inches	40	8		Wind	S		20	50.00
T. A. Elliot	33	18	24	1857	Bored, 5 inches	40	11	67	Hand	D		120	4.00
W. H. & J. F. Putnam	4	19	24		do	49	7	68	do	D		25	4.00
A. B. Reese	4	19	24	1890	do	60	8		Wind	I		30	40.00
Oscar Evans	26	18	24	1903	do	40	6	66	Hand	D		25	3.50
J. J. & W. J. Fulgham	35	18	24	1905	Bored, 6 inches	48	8?		Gas	D, I, S		25	250.00
R. E. Hyde	25	18	24		Bored, 7 inches	45	4	66	Hand	D		30	4.00
Geo. Pechter	2	19	24	1888?	Bored, 5 inches	68	4	64	do	D, S		35	4.00
W. H. Roeben	2	19	24		do	28	8		Wind	S		25	35.00
Philip Aulman	2	19	24		Bored, 8 inches	40	6		do	S		20	60.00
Do	2	19	24	1896	Bored, 5 inches	58	5.5		do	D, S		30	75.00
G. Schmidt	1	19	24		do	40	6	63	Hand	D, S		20	4.00
E. H. & Alfred Daggett	1	19	24	1899	Bored, 10 inches	40	7		Steam	I	44	40	1,500.00
A. Koch	1	19	24	1904	Bored, 5 inches	34	5.5	63	Hand	D, S		20	4.00
Earnest Volguards	1	19	24	1902	Bored, 10 inches	50	7		Gas	I	10	54	300.00
A. T. Griffin	1	19	24	1895	Bored, 5 inches	60	8	62	Hand	D, S		30	4.00
R. Miller	6	19	25	1904	Bored, 6 inches	42	15		do	S		20	4.00
J. J. Schueller	6	19	25		Bored, 5 inches	54	4	61	do	S		30	4.00
M. L. Caldwell	6	19	25	1900	do	65	5	64	do	D		35	4.00
Clem Caldwell	1	19	24	1902	do	80	7.5	64	do	D		40	3.00
S. B. Irwin	12	19	24	1904	Bored, 4 inches	40	8	62	do	S		20	4.00
P. K. Reese	6	19	25	1903	Bored, 5 inches	50	8	62	do	D, S		25	3.50
R. Miller	6	19	25	1890	Bored, 6 inches	52	8		Wind	D, S		25	200.00
Mr. Shella	6	19	25	1895	do	40	6		Hand	D		20	4.00
Mrs. E. Foran	30	18	24		Bored, 5 inches	48	3	68	do			25	4.00
Mrs. M. Smith	30	18	25		do	60	4		do	D			
Visalia City Water Co	30	18	25	1902	Bored, 10 inches	[b] 75	8		Electric	D	44		
Do	29	18	25	1891	Bored, 12 inches	[c] 110	8		do	D	[a] 90		
Morgan & Alge	28	18	25	1898	Bored, 5 inches	65	4	65	Hand	D, S			

[a] Yield estimated or statement of owner taken.

[b] Two wells.

[c] Four wells.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location. Section.	Township south.	Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
E. O. Miller	28	18	25		Bored, 5 inches	35	3.5	65	Hand	S, D			
G. F. Beales	32	18	25	1894	do	45	4.5		Gas	D			
B. R. Dennig	28	18	25	1894	do	42	5	65	Hand	D			
Albert Welsh	32	18	25		Bored, 7 inches	66	9	61	do	D		$50	
J. K. Yocum	5	19	25	1902	Bored, 5 inches	34	5	62	do	D, S		17	$3.00
B. A. Graves	5	19	25		Bored, 6 inches		5		Horse	D, S			100.00
G. W. Bence	5	19	25		Bored, 5 inches	24	6	61	Hand	D, S		16	5.00
S. C. Brown	4	19	25		do	24	4	62	do	D		15	3.50
Herbert Luewe	4	19	25		do		5	62	do	D, S			3.50
F. Duran	27	18	25	1880	do	60	5	65	do	D, S			
Fred Uhl	34	18	25		do	45	5	65	do	D			
J. W. Nelson	3	19	25	1904	do	64	3	63	Wind	D, S		31	35.00
J. F. Ames	3	19	25	1905	Bored, 12 inches	26	7		do	D, S		37	40.00
W. H. Blane	3	19	25		Bored, 5 inches	37	4	60	Hand	S		20	3.00
Do	3	19	25	1904	do	22	5	62	do	D		15	4.50
Lewis Whittendale	35	18	25	1884	do	52	6	65	do	D			
L. Mathewson	2	19	25		Bored, 6 inches	65	8	62	do	D			
R. K. Ogden	3	19	25		Bored, 5 inches	50	10	62	do	D, S		35	3.50
L. J. Mills	11	19	25	1881	do	60	15?	62	do	D		40	3.50
L. Mathewson	2	19	25		Bored, 10 inches	65	8		Gas	I	66	70	400.00
Wong Sung	2	19	25		Bored, 6 inches	31	5	62	Hand	D, S		25	4.00
J. P. Dillon	2	19	25	1903	do	74	7	63	do	D, S		50	4.00
Geo. Morrell	1	19	25	1901	do	60	7?	62	do	D, S		40	3.50
Nellie Lawlers	1	19	25		do	30	6	66	do	D		20	4.00
A. M. Thompson	1	19	25		do	60	8	70	do	D		45	
F. Van Lome	6	19	26	1903	do	40	8	68	Wind	D, S		20	35.00
Farmersville village	6	19	26		Bored, 4 inches	38	6	67	do	D, S			
C. K. Avery	6	19	26	1903	Bored, 6 inches	34	12	66	Hand	S		17	3.00
L. A. Martin	6	19	26		Bored, 4 inches	43	10	77	do	D		20	
W. Polly	6	19	26	1890	do	60	4	67	do	D, S		30	
Grant Oak Fruit Co	7	19	26		Bored, 5 inches	30	4	65	do	S			
H. A. Scott	25	18	25	1880?	Bored, 7 inches	103	7	65	do	D. S			
Deep Creek school district	31	18	26		Bored, 5 inches		7.5	64	do	D			
George Neilson	32	18	26	1893	Bored, 4½ inches	56	4		Wind	D, S			
Mrs. E. A. Buckman	33	18	26	1889	Bored 5 inches	40	9?		Wind, hand	D, S			
B. Schweitzer	27	18	26		Dug, 3 feet	18	13	68	Hand	D			
O. H. Fanis	34	18	26	1905	Bored, 7 inches	78	19		Gas	I	a 60		b1,000.00
Mrs. A. M. Catron	4	19	26	1880	Bored, 5 inches	38	15	67	Hand	D			

C. M. Noell	3	19	26		Bored, 4 inches	35	14	67	do	D			
D. V. Robinson	26	17	25	1895	Bored, 7 inches	40	12	70	Wind	S			
H. H. Newman	25	17	25	1892	Bored, 5 inches	50	7	69	Hand	S		25	
J. W. Bacon	24	17	25		do	41	8	68	do	D		20	
M. V. Arnold	30	17	26		Bored, 6 inches	33	13	70	Wind	S			
Mrs. M. F. Swank	30	17	26	1887	Bored, 5 inches	38	12	72	Hand	D			
H. T. Anderson	4	19	26	1890	Bored, 6 inches	35	12	70	Wind	D			
Dillon estate	8	19	26		Bored	40	16	67	do	S			
V. B. Humphrey	4	19	26	1890	Bored, 5 inches	44	15	67	do	S		33	
A. Johnson	9	19	26	1891	do	30	14	65	Hand	D		25	
Frank Emery	3	19	26	1903	Bored, 10 inches	90	26	72	Gas	I	18		b 750.00
J. F. Firebaugh	3	19	26	1904	do	113	31		Electric	I	a 48	500	1,000.00
C. N. Jordan	3	19	26	1904	do	84	32	72	do	I	15		
B. F. Teague	10	19	26	1903	do	60	26		Gas	D	8		
Ostrander & Son	11	19	26	1901	do	99	30		Electric	I	28		
Horace Davis	10	19	26	1905	do	76	30		Gas	I	2		
Norcross & Crane	11	19	26	1904	Bored, 8 inches	85	31	72	Electric	I	26		
B. F. Teague	11	19	26	1904	Bored, 10 inches	85	30	72	do	I	16	160	
Pozo Grande Vineyard	2	19	26	1904	do	128	42	72	do	I	48		
F. Moxon	3	19	26	1902	do	95	32	70	do	I	a 3	200	850.00
H. Lacesse	2	19	26	1903	Bored, 6 inches	62	42	66	Wind	D		30	125.00
A. R. Carney	2	19	26	1890	Bored, 10 inches	65	40	67	Electric	I		45	650.00
E. Patten	1	19	26	1903	do	100	40		do	I	40	125	950.00
Do	11	19	26		Bored, 5 inches	56	38	68	Hand	D			
C. E. Joyner	12	19	26	1885	Bored, 6 inches	62	40	68	Wind	D		62	
T. W. Potter	35	18	26	1905	Dug, 2 feet	90	42	72	Electric	I	31		
J. P. Daly	35	18	26	1888	Bored, 5 inches	62	30		Wind, hand	D, S			
A. R. Carney	36	18	26		Bored, 10 inches	+90	42		Electric	I	18		
Do	36	18	26		do	65	41	72	do	I	22		
Do	25	18	26		do	65	40	72	do	I	22		
Merriman Fruit, Land & Lumber Co	36	18	26	1903	do	250	43	71	do	I	b 9	250	
Do	36	18	26	1903	do	80	38		do	I	18		
Badgar Irrigation Co	30	18	27		do	85	40		do	I	a 19		
Do	30	18	27	1898	do	85	31		do	I	a 25		
Do	31	18	27	1902	do	85	44	70	do	I	a 40		
Roeding & Wood	12	19	26	1904	do	110	32	70	Gas	I	12	220	1,000.00
A. Ahlin	24	19	26	1897	Bored, 4 inches	46	30	72	do	I			
M. E. Newhall	18	19	27		Bored, 10 inches	90	33		Electric	I	31		
Wm. Mitchel estate	19	19	27	1904	do	75	32		do	I	40	200	800.00
J. F. Dungan	19	19	27	1903	do	65	26	72	do	I	16		
A. N. Dreisbach	19	19	27	1903	Bored, 4 inches	50	20	74	do	I	15	75	500.00
Burr Bros	19	19	27	1898	Bored, 8 inches	65	20	71	Wind	D, S			
Lindsay Heights Water Co	30	19	27		Bored, 11 inches	107	28	69	Electric	I	38		
Do	30	19	27		do	75	28	69	do	I			
Do	30	19	27		do	110	28	70	do	I	32		
W. E. Carder	10	19	26	1902	Bored, 5 inches	43	20	73	Wind	D, S		30	
Mr. Bowman	14	19	26		Dug	30	24	69	Hand	S			
S. H. West	15	19	26	1890	Bored, 6 inches	40	20	73	Wind	D, S			
J. Tuohy	16	19	26		do	60	13	68	do	D, S			
J. H. Hart	22	19	26	1885	do	20	14	72	Hand	D			
H. T. Anderson	21	19	26		Bored, 5 inches	30	16	72	do	D			

a Yield estimated or statement of owner taken.

b Cost of well and equipment combined.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
B. F. Dailey	22	19	26	1904	Bored, 10 inches	60	14	72	Gas	I	18		$350.00
Kibler estate	23	19	26		Dug, 2 feet	24	20	72	Wind	S			
C. W. Hart	21	19	26		Bored, 5 inches	26	9	70	do	S			
R. S. Vanderburg	28	19	26		Bored, 6 inches	20	9	72	do	S		$10	
Do	28	19	26	1903	Bored, 10 inches	70	9	73	Horse	I		70	50.00
A. C. Kuhn	18	19	26	1904	do	50	15						
C. W. Hart	20	19	26	1905	Bored, 5 inches	50	10	68	Hand	D		25	
School district	18	19	26		do	50	11	69	do	D			
B. F. Bequette	19	19	26	1890	do	34	11	69	do	D		17	
Mrs. F. D. Rice	30	19	26	1885	do	50	8	69	do	D		25	
J. Rice	19	19	26	1897	Bored, 4 inches	62	8	71	do	D, S		30	
L. N. Wood	25	19	25		Bored, 5 inches	46	8	70	Wind	D, S			
E. F. Hart	12	19	25		do	70	6	63	Hand	D		45	10.00
Pasco Bequette	11	19	25		do	39	4	62	do	D, S		25	3.00
J. W. Hart	13	19	25	1880	do	42	14?	62	do	D, S		40	4.50
John Markes	14	19	25	1890	Bored, 6 inches	60	10	62	do	D, S		30	3.00
J. C. Campbell	24	19	25	1892?	Bored, 8 inches	47	8		Wind	D, S		35	
J. W. Griffin	24	19	25	1890	do	72	10?	65	Hand, wind	D		50	30.00
W. A. Mills	11	19	25	1891	Bored, 5 inches	33	6	64	Hand	D, S		20	3.50
J. M. Dye	11	19	25		do	32	7	63	do	D		20	3.50
Sam Huth	15	19	25		do	33	6	64	do	D		20	3.50
Joe Summers	10	19	25	1905	do	46	7	65	do	D		35	3.50
London, Paris & American Bank	15	19	25	1899	Bored, 10 inches	110	10		Gas	I	*a* 300	110	1,400.00
W. S. Winans	34	19	25		Bored, 5 inches	41	4	64	Hand	D, S		25	4.50
Mr. Doherty	26	19	25		do	23	5		Wind	D, I, S		15	65.00
Wm. Swall	35	19	25		do	38	4.5	64	Hand	S		24	5.00
Jas. H. Morton	28	19	25	1897	Bored, 10 inches	85	10		Electric	I	} 144	300	1,300.00
Do	28	19	25	1897	do	65	10		do	I			
Wm. Swall	29	19	25	1902	Bored, 7 inches	65	10	62	Steam	I		65	260.00
J. C. Mosier	20	19	25	1888	Bored, 10 inches	34	8	64	Hand	D, S		30	5.00
London, Paris & American Bank	16	19	25		Bored, 5 inches	41	10		Wind	D, S		21	75.00
H. C. Higby	8	19	25	1870	do	40	8	61	Hand	D		30	5.00
F. J. Tucker	12	19	25	1905	Bored, 6 inches	42	6	65	do	S		25	4.50
G. H. Hubbell	18	19	25	1874	Bored, 5 inches	60	8	63	do	D		30	3.50
John C. Hawkins	19	19	25	1887	do	30	10	63	do	D, S		15	4.50
Geo. Swall	20	19	25		Bored, 8 inches	49	9	64	do	D, S		35	9.00
Mr. Reeves	29	19	25		Bored, 5 inches	34	11	64	do	D, S		15	4.00
William Swall	29	19	25	1904	Bored, 8 inches	50	10	64	do	D, S		35	10.00

Mrs. M. A. Edgar	32	19	25	1904	Bored, 5 inches	105	12	62	do	D, S		50	4.00
J. P. Brown	30	29	25		Bored, 5 inches	62	10	63	do	D		30	4.00
A. W. Smith	31	19	25	1901	Bored, 2 inches	60	10	65	Wind	D, S			60.00
John Mantz	30	19	25		Bored, 7 inches	24	10	65	do	S		20	65.00
A. H. Collins	2[illegible]	19	24	1903	Bored, 5 inches	44	14	64	Hand	D		25	4.00
G. W. Filmore	24	19	24		do	65	10	64	Wind	S		30	75.00
E. H. Fisher	19	19	25	1903	do	78	10	65	Hand	S		45	22.00
C. R. Scott	19	19	25	1891	Bored, 6 inches	47	10	62	do	D, S		25	4.00
A. O. Carmichael	13	19	24		Bored, 8 inches	32	7		Horse	D, S		25	60.00
E. O. Larkin	12	19	24		do		7		do	D, S			100.00
Do	12	19	24	1899?	Bored, 5 inches	70	5	64	Hand	D		35	4.00
J. H. Kinkaid	12	19	24	1886	do	38	8		do	D		20	4.00
John Findley	14	19	24	1891	do	50	7	64	do	D, S		25	15.00
A. E. Glare	13	19	24		Bored, 6 inches		8	64	do	D, S			4.00
Mrs. D. K. Zumalt	13	19	24		do	40	12?	64	do	D, S		20	4.00
Mrs. Emma Zumalt	23	19	24		Bored, 10 inches	70	8		Steam	S		70	150.00
I. L. Jimmerson	24	19	24		Bored, 8 inches	50		66	Wind	D, S		35	60.00
D. L. Bickley	25	19	24	1904	Bored, 5 inches	46	10		do	S		25	40.00
J. M. Segress	25	19	24		do	60	8	65	Hand	D		30	4.00
Mrs. M. McKamish	25	19	24		Bored, 8 inches	48	9		Horse	S		35	75.00
Wm. Bruce	26	29	24	1881	do	51	11	66	Hand	D		40	4.00
J. R. Williams	35	19	24		Bored, 5 inches	50	10	68	do	D, S		25	4.00
Mrs. Emma Zumalt	23	19	24	1902	Bored, 6 inches	30	8		do	S		15	4.00
Wm. Robertson	16	19	24		Bored, 5 inches		11	60	Wind	D, S			50.00
Albert Nelson	15	19	24	1887	Bored, 6 inches	34	11	69	do	D, S		20	65.00
Goldman & Bachman	21	19	24	1903	Bored, 11 inches	65	10		Gas	I		65	
Do	21	19	24	1903	do	85	10		do	I		85	
E. Renaud	22	19	24	1880	Bored, 5 inches	60	11		Wind	S		30	45.00
F. J. Gist	28	19	24	1887	do	60	11	66	Horse	D, S			
H. P. Anderson	27	19	24	1903	do	65	8		Wind	D, S		33	45.00
Mr. Barber	27	19	24	1905	do	75	10		Hand	D		40	4.00
F. J. Gist	28	19	24		do	45	9	65	Horse	D, S		25	60.00
E. Lathrop	28	19	24		Bored, 8 inches	32	9	68	Wind	D. S		25	75.00
F. P. Robertson	33	19	24	1884	do		10		do	D. S			65.00
T. T. Sullivan	33	19	24		Bored, 5 inches		9	67	Hand, horse	D, S			25.00
Alzina Benc	29	19	24	1884?	Bored, 6 inches	38	8	68	Hand	D, S		20	4.00
W. G. Parsons	32	19	24		Bored, 7 inches	60	13	70	Wind	D, S		35	50.00
Thomas J. Barringer	29	19	24		Bored, 5 inches	72	15	68	Hand	D		35	4.00
John Moller	20	19	24	1893	Bored, 4 inches	30	15	68	Wind	D, S		15	45.00
I. D. Reinhart	20	19	24		Bored, 5 inches	24	8	69	Hand	D		15	4.00
P. E. Reinhart	21	19	24	1901	Bored, 6 inches	43	6		Wind	D, S		20	65.00
A. Mitchell	8	19	24	1888	Bored, 5 inches	70	12?	68		D		35	4.00
C. Hausch	7	19	24	1874	Bored, 4 inches	36	15		Wind	S		20	50.00
Do	7	19	24	1897	do	36	15		do	S		20	50.00
Wm. March	12	19	23	1902	Bored, 5 inches	44	7	69	do	S		20	50.00
Chas. Hausch	13	19	23	1899	Bored, 6 inches	60	12?	68	Hand	D		30	50.00
B. Noussiton	24	19	23	1888	Bored, 10 inches	53	11		Wind, horse	D. S		40	
Geo. Heidt	19	19	24	1881	Bored, 5 inches	50	9?	69	Wind	D, I		25	50.00
Henry Colpien	29	19	24	1900	Bored, 4 inches	50	15		do	D, S		25	55.00
E. M. Pugh	29	19	24		Bored, 5 inches	60	14		Not raised	N		30	
S. S. Inge	31	19	24	1875	Bored, 4 inches	64	11		Wind	D, S		30	45.00

a Yield estimated or statement of owner taken.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location. Section.	Township south.	Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
M. A. Moorehead	30	19	24	1890	Bored, 7 inches	32	8	66	Wind, hand	D, S		$16	$5.00
Oakland Savings Bank	36	19	23	1903	Bored, 10 inches	465	1.5	76	Electric	I	*a* 110	1,800	100.00
Do	36	19	23		do	580	4		Not raised	N			
Frank Mattos	26	19	23	1895	Bored, 6 inches	62	12		Wind	S		30	50.00
W. J. Brown	24	19	23	1903	Bored, 8 inches	35	12		Hand	D		20	4.00
Do	24	19	23	1905	Bored, 6 inches	21	12		do	S		10	4.00
Henry Banker	12	19	23	1902	Bored, 5 inches	24	8		Wind	S		12	50.00
R. Chatten	11	19	23	1862	Bored, 6 inches	40	9	69	Horse	D, S			50.00
Linder school district	27	19	23		Bored, 5 inches	102	13	69	Hand	D		50	4.00
John Fleming	34	19	23	1885	do	48	16	69	do	D. S			18.00
Do	28	19	23	1903	do	68	16		Wind	S			50.00
M. & J. Fleming	34	19	23	1898	do	78	16		Not raised	N		40	
B. T. Watson	28	19	23	1904	Bored, 12 inches	61	12		Gas	I		60	600.00
Wm. Hoffsneider	19	19	23	1903	do	171	14		do	I		170	1,000.00
A. Baird	29	19	23	1884	Bored, 8 inches	420	0	75	Artesian	I	8	1,000	
R. E. Keeler	31	19	23	1884	do	430	0	76	do	I	5	1,000	
Louis Bertch	4	20	23		Bored, 7 inches	80	10	71	Hand	D		50	4.00
Mrs. Geo. Bertch	7	20	23	1882	do	470	0	74	Artesian	I, S		1,200	
Do	7	20	23	1895	Bored, 9 inches	60	8		Steam	I		60	6.00
San Francisco Savings Union	18	20	23	1882	Bored, 7 inches	462	0	74	Artesian	S, I	2		
Manuel Machado	17	20	23		Bored, 5 inches	58	11	72	Hand	D		30	4.00
Jacob Bertch	16	20	23	1885	Bored, 7 inches	480	0	74	Artesian	I	14	1,000	
E. H. Kemble	9	20	23	1892	Bored, 8 inches	36	16?	68	Hand	D, S		25	4.00
S. F. Hoover	10	20	23	1888	Bored, 9 inches	505	0	74	Artesian 5	I, D	6		
Page & Monteagle	3	20	23		Bored, 5 inches	68	7	66	Wind	S		35	50.00
Do	3	20	23		Bored, 8 inches	60	7		Horse	S		35	50.00
Albert Knapp	11	20	23	1891?	Bored, 9 inches	1,150	0	75	Artesian	I	21	2,000	
C. M. Hatch	11	20	23	1887	Bored, 7 inches	441	0		do	I	17		
Do	11	20	23	1899	Bored, 12 inches	87	11.5		Steam	I		200	1,000.00
I. P. Beal	14	20	23		Bored, 8 inches	80	8		Horse	D, S		60	50.00
J. Goldman & Co.	12	20	23	1899	Bored, 5 inches	40	10	69	Hand	D, S		20	4.00
John Hanesy	1	20	23	1905	Bored, 12 inches	600	0		Electric	I	*a* 83	1,500	600.00
Samuel Handy	7	20	24		do	*b* 147	8		do	N		200	
Do	7	20	24		do	90	8?		do	N			
Laurel school district	6	20	24		Bored, 5 inches	46	13		Hand	D		20	4.00
W. C. Carpenter	5	20	24		do	34	13	68	do	D, S		20	4.00
J. R. Clemens	32	19	24		Bored, 7 inches	700?	12		Wind	D, S			65.00
D. J. Knapp	5	20	24		Bored, 6 inches	65			Hand	S		40	4.00

C. H. Slaughter	4	20	24	1893	do	60	8	66	do	D		35	4.00
T. J. Mull	5	20	24	1901	Bored, 11 inches	430	7.5	73	Electric	I	24	700	1,000.00
Page & Monteagle	8	20	24	1900	do	170	15	70	do	I	110		c4,000.00
Do	8	20	24	1900	do	170	15	70	do	I	76		
Mrs. Geo. Bertch	4	20	24	1903	Bored, 5 inches	116	13	68	Hand	D, S		76	4.00
G. W. Frees	9	20	24	1903	Bored, 6 inches	56	13	65	do	D, S		35	4.00
R. B. Holcomb	4	20	24	1886	Bored, 8 inches	58	10	67	do	D, S		50	4.00
J. H. Morton	3	20	24		Bored, 10 inches	80	12		Horse	D, S		80	75.00
Tulare City Water Co	10	20	24	1887	do	525	12		Electric	D		1,348	
Do	10	20	24	1887	do	490	12		do	D	166		
Do.b	10	20	24	1887	Bored, 8 inches	350	12		do	D			
C. Ellison	34	19	24	1904	Bored, 5 inches	40	8?	70	Hand	D, S		20	4.00
G. Linegrover	34	19	24		do	34	5	66	Wind and hand	S		20	60.00
F. H. Butler	35	19	24	1903	do	85	10	66	Wind	D, S		50	45.00
U. S. G. Mills	35	19	24	1903	do	45	12	68	Hand	D, S		35	4.00
A. G. Woodward	11	20	24	1897	do	34	9	70	do	D		20	4.00
S. Gavatte	12	20	24		do	23?	11		Horse	D, S			50.00
O. F. Manock	13	20	24	1903	Bored, 6 inches	68	15	66	Hand	D, S		30	4.00
D. Kazaian	1	20	24		Bored, 5 inches	62	9	68	do	D, S		30	4.00
J. M. Smith	6	20	25		do	40		68	Wind	D, S		20	30.00
A. M. Wells	6	20	25		do	61	9	67	Hand	D, S		30	4.00
D. J. F. Reed	7	20	25		do	60	9	66	do	D, S		30	4.00
T. N. Johnson	7	20	25	1883	Bored, 8 inches	700	8.5		Wind	D, S		1,600	50.00
Tulare Colony	5	20	25		Bored, 5 inches	60	9.5		do	D, S		30	50.00
M. Brown	32	19	25	1901	do	60	4?	67	Hand	D, S		30	4.00
W. Isley	32	19	25	1893	do	44	9	67	do	D		45	4.00
A. N. Budd	5	20	25	1902	do	60	12?	67	do	D, S		40	4.00
W. H. Kelley	32	19	25	1900	do	65	8	67	do	D, S		35	4.00
J. T. Lawson	32	19	25		do		7	66	Wind	D, S			50.00
A. Peterson	5	20	25	1903	Bored, 7 inches	34	5		do	S		25	40.00
W. T. Caldwell	5	20	25		Bored, 5 inches	36	4	67	do	D, S		20	50.00
C. M. Medder	4	20	25	1904	do	52	4	69	Hand	D, S		25	4.00
C. J. Shannon	33	19	25		Bored, 7 inches	49	5	64	do	D		40	4.00
G. W. Gluyas	33	19	25	1901	Bored, 5 inches	+100	3	67	do	D, S			4.00
F. C. Wagner	4	20	25		Bored, 7 inches	36	3.5		Horse	S		25	50.00
F. Gianini	3	20	25		Bored, 5 inches	37	5.5		Wind	S		20	50.00
Albert Henry	34	19	25		do	46	7	68	Hand	D, S		25	4.00
F. Pospishek	11	20	25	1905	do	49	3.5	67	do	D		24	4.00
J. M. Birkhead	12	20	25	1902	Bored, 7 inches	21	3.5		Not raised	N		15	
H. Mohr	1	20	25		Bored, 5 inches	60	4		Hand	S		30	4.00
Judge Gray	36	19	25	1893	do	56	8	70	do	D		30	
J. F. Sullinger	6	20	26	1902	Bored, 6 inches	48	12	72	Gas	D, S	7	35	200.00
H. Mohr	6	20	26		Bored, 5 inches	33	8	71	Hand	D, S			
R. E. Hyde	12	20	25		do	24	3.5	68	do	S		10	4.00
P. Burkhead	12	20	25		Bored, 6 inches	31	9	69	Wind	D, S			
G. W. Wray	7	20	26		Bored, 5 inches	28	9	72	do	S			
G. Baumann	4	20	26	1893	do	40	12	70	do	D, S		20	50.00
T. Stillwell	33	19	26	1901	Bored, 6 inches	30	9	70	do	D, S		20	40.00
J. W. Archer	34	19	26		Bored, 5 inches	26	9		do	S			
T. Stillwell	34	19	26	1901	Bored, 6 inches	30	8	71	do	S		20	35.00
Do	26	19	26	1901	do			69	do	D, S		20	40.00

a Yield estimated or statement of owner taken. b Two wells. c Cost of well and equipment combined.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
C. P. Mayberry	34	19	26	1905	Bored, 10 inches	58	14		Gas	I	15	$75	$165.00
J. W. Sturgeon	4	20	26		Bored, 5 inches	39	11	68	Wind	S			
A. Swanson	3	20	26		do	40	12	72	do	D, S			
Mrs. S. Navarre	2	20	26		do	60	18	70	Hand	D			
J. Huskins	2	20	26	1885	Bored, 7 inches	45	22	72	do	D		25	
Mrs. W. R. Ray	2	20	26	1883	Bored, 5 inches	40	14	73	Wind	D, S			
J. C. Green	6	20	27	1905	Bored, 8 inches	65	28	75	Electric	I			
J. Taylor	6	20	27	1902	Bored, 9 inches	85	43	75	do	I	} 18	{ 85	} 750.00
Do	6	20	27	1902	do	150	43	73	do	I		150	
J. McKeller	6	20	27	1905	Bored, 10 inches	150	29	72				150	
G. K. Hostetter [a]	6	20	27	1905	Bored, 8 inches	250	38	73	Gas	I	22	500	600.00
J. McKeller	6	20	27	1901	Bored, 11 inches	130	46		Electric	I	8		*b* 800.00
Camille Ranch Co	5	20	27	1905	Bored, 12 inches	245	52	73	do	I	42		3,000.00
Do	5	20	27	1898	(*c*)	70	40	69	do	I	7		
H. W. Dunlap	5	20	27	1905	Bored, 10 inches	225	24		do	I	*d* 9		*b*1,000.00
Fuller & Graybill	32	19	27	1905	Bored	220	70	75	Gas	I	10		*b*2,600.00
W. S. Galyan	32	19	27	1905	Bored, 10 inches	187	100	74	Electric	I	8		
John Hedberg	4	20	27	1905	do	153	82		do	I	*d* 12		*b* 762.00
E. L. Daniels	4	20	27	1903	do	185	60			I	*d* 15		
D. O. Bishop	4	20	27	1904	do	200	60	75	Electric	I	6		1,500.00
F. J. Fountain	5	20	27	1902	Bored, 8 inches	190	60	73	do	I	6		
A. Godding	5	20	27		Bored, 10 inches	175	62	71	do	I	4		
A. E. Berry	5	20	27	1900	do	200	45		do	I			
W. B. Buxton	4	20	27	1904	Bored, 8 inches	176	78	74	do	I	*d* 5		
Whitmore Bros	4	20	27	1904	Bored, 10 inches	250	84		do	I	12	700	2,000.00
Do	4	20	27	1900	(*e*)	157	87		do	I	*d* 7	350	800.00
John Hedberg	3	20	27	1905	Bored, 10 inches	191	42		do	I	*d* 32	500	2,300.00
J. L. Tuohy	2	20	27	1905	Dug	17	11		do	I	*d* 7		
E. A. Batchelder	10	20	27		Bored, 11 inches	170	40		Gas	I	20		*b* 550.00
W. F. Cowan	9	20	27	1905	Bored, 12 inches	153	67	74	Electric	I	4		*b* 725.00
C. R. Rice	9	20	27	1905	do	197	70		do	I	*d* 5	325	800.00
C. H. Boardman	16	20	27	1905	do	165	70		do	I	6		1,150.00
J. N. Bergen	9	20	27	1904	Bored, 8 inches	140	65		Gas	I	4		600.00
Nob Hill Water Co	8	20	27	1900	(*f*)	190	65		Electric	I	38		*b*2,000.00
N. S. Marshall	16	20	27	1905	Bored, 10 inches	201	60		do	I	13		1,400.00
C. Hendricks	7	20	27	1905	Bored, 8 inches	130	60	74	Gas	I	2	65	105.00
J. N. Birkhead	7	20	27	1905	Bored, 10 inches	124	47		do	I	11		*b*1,050.00
A. Z. Roberts	7	20	27	1904	do	148	47		Electric	I	1		

Mrs. A. H. Hersey	18	20	27	1905	do	210	52	74	do	I	38		2,000.00
J. de Martini	17	20	27	1903	Bored, 12 inches	225	58?		do	I	d 30		
Do	17	20	27	1905	do	215	60	74	do	I	35		
Ruby Johnson	18	20	27	1900	Bored, 10 inches		47		do	I	9		
W. C. Stelling	18	20	27	1902	Bored, 8 inches	80	45?		do	I			b1,000.00
J. O. Culver	17	20	27	1904	Bored, 10 inches	138	51	74	do	I	7		1,050.00
K. H. Plate	18	20	27	1902	do	180	50	74	do	I	17		
Do	18	20	27	1902	do	130							
Lindsay Irrigation Co. g	18	20	27	1901	do	80	55		do	I	22		
C. O. Cowles	18	20	27	1903	Bored, 8 inches	182	42		do	I	14		b1,000.00
Hugh Latimer	18	20	27	1900	Bored, 10 inches	160	45		do	I			
Do	18	20	27	1900	do	90							
J. E. Coombs	18	20	27	1904	Bored, 12 inches	81	56?	74	do	I	12		
Mrs. E. G. Stelling	7	20	27	1903	Bored, 8 inches	145	45?		do	I	9		b1,500.00
E. C. Graham	7	20	27	1904	do	142	47	74	do	I	1		
C. J. Carle	7	20	27	1899	Bored, 10 inches	148	26		do	I	14		1,200.00
Mount Whitney Power Co	7	20	27	1904	Bored, 13 inches	208	47	74	do	D	11		
Camille Ranch Co	12	20	26	1897	Bored, 10 inches	65	40		do	I	7		
Lindsay Water Development Co	12	20	26	1900	do	82	42	74	do	I	75		
Do	12	20	26	1900	do	500							
L. S. White	12	26	26	1899	do	135	48	74	do	I	16		
Do	12	20	26	1899	do	95							
R. E. Pierce	12	20	26	1895	do	170	45		do	I	23		
Do	12	20	26	1895	do	85							
C. O. Cowles	12	20	26	1902	Bored, 8 inches	142	40	74	do	I	5		b 500.00
G. W. Fletcher	13	20	26	1905	Bored, 10 inches	93	40	72	do	I	10	36	500.00
Paradise Water Co	13	20	26	1900	Bored, 12 inches		45?	74	do	I	27		
Mrs. M. E. Irwin	12	20	26	1903	Bored, 10 inches	70	49	74	do	I	17		
J. W. Graybill	12	20	26	1900	Bored, 8 inches	70	40	73	do	I	8	50	
S. Wolf	12	20	26	1905	do	75	40		do	I	d 16		
W. E. Porter	12	20	26	1901	do	75	40	73	do	I	11	75	400.00
J. B. Eager	12	20	26	1900	do	80	29?		do	I	11		350.00
W. McIndoo	12	20	26	1905	do	70	38		do	I	20	50	600.00
McIndoo & McLeis Bros	11	20	26	1904	Bored, 10 inches	85	40	73	do	I	d 28		
J. Goldman	13	20	26	1899	do	80	40		do	I	d 37		1,250.00
J. Orton	14	20	26	1885	Bored, 7 inches	50	26	74	Hand	S			
J. T. Orton	13	20	26	1890	do	40	30	73	Wind	D, S			
Keeley Bros	24	20	26	1890	do	50	30	70	Hand	D, S			
J. J. Cairns	11	20	26	1900	Bored, 10 inches	70	20	69	Electric	D, S	4	50	
Do	11	20	26	1902	do	75	20		do	I	d 60		
Do	11	20	26	1891	Bored, 12 inches	275	20		do	I	d 135		
M. R. Madary	11	20	26	1903	Bored, 6 inches	200	30	71	do	I	d 56		
T. N. Jarrard	10	20	26	1885	Bored, 7 inches	40	20	69	Wind	D		25	50.00
R. A. Rodgers	16	20	26	1904	Bored, 6 inches	28	11	69	do	D, S			
S. Bond	20	20	27	1895	Bored, 5 inches	62	36		do	D		60	
A. Hunsaker	20	20	27	1885	do	60	40	74	do	D, S			
J. Goldman	30	20	27	1882	Bored, 6 inches	50	34		do	D, S			
J. B. Chinn	21	20	27	1895	Bored, 7 inches	70	40	76	do	D, S		70	

a Two wells.
b Cost of well and equipment combined.
c Dug 6 by 6 feet 40 feet deep and bored 30 feet by 12 inches diameter.
d Yield estimated or statement of owner taken.
e Dug 82 feet and bored 75 feet by 8 inches diameter.
f Dug 80 feet and bored 110 feet by 12 inches diameter.
g Six wells.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location. Section.	Township south.	Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of machinery.	Cost of well.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
Strathmore ranch	27	20	27		Bored, 10 inches	203	51		Not raised	N			
Do	27	20	27		Bored, 15 inches	220	60		do	N			
Do	27	20	27		Bored, 12 inches	227	68		do	N			
El Mirador Land Co	23	20	27	1905	Bored, 10 inches	283	65	70	do	I			$2,000.00
P. J. Montgomery	24	20	27	1905	Bored, 12 inches	301	70?		do	I			2,000.00
Strathmore ranch	35	20	27		do	220	44		Not raised				
P. Griffin	2	21	27	1880	Bored, 6 inches	35	18	69	Wind	D, S			
J. K. Cramer	2	21	27	1898	Bored, 7 inches	70	16		Horse	I		$54	125.00
J. Linden	34	20	27	1903	do	85	16	70	Wind	D			
J. M. Van Emon	32	20	27		Bored, 6 inches	56	20	71	do	D, S		60	
J. Weisenberger	10	21	27	1905	Bored, 12 inches	175	35	71	do			480	75.00
C. W. Buswell	10	21	27	1904	Bored, 10 inches	195	16	74	Electric	I	*a* 13		870.00
Hemphill & Larson	14	21	27	1904	Bored, 12 inches	64	38		do	I	*a* 15	63	1,500.00
Sunnyside Water Co.[b]	23	21	27	1902	Bored, 10 inches	100-150	20	71	do	I	*a* 40		
Hilo Pump	23	21	27	1904	Bored, 12 inches	165	42		do	I	*a* 45	600	4,000.00
J. H. Williams & Co	21	21	27	1902	Bored, 8 inches	30	4	68	Hand	D			
F. A. Kelly	21	21	27	1897	Bored, 5 inches	36	7	70	do	D			
F. E. Henderson	20	21	27	1882	Bored, 7 inches	44	7	70	Wind	D, S		45	
W. H. Castle	17	21	27	1895	Bored, 5 inches	30	6	69	Hand	D		15	
A. Hansaker	13	21	26		Bored, 6 inches	43	8	67	do	D			
Mrs. R. Kirby	11	21	26	1899	Bored, 4 inches	30	9	66	do	D			
J. B. Chinn	14	21	26	1890	Bored, 6 inches	40	10	70	Wind	S			
M. Braverman	15	21	26		Bored, 5 inches	40	9	70	Hand	D, S		40	
Kelley Bros	11	21	26	1893	do	52	9		do	S			
F. Stone	10	21	26	1885	do	50	10	66	do	D		50	
P. Spuhler	10	21	26	1885	Bored, 8 inches	46	9	67	Wind	S			
O. Miller	34	20	26	1875	Bored, 7 inches	33	9	69	Horse	S		30	
P. Spuhler	9	21	26	1887	do	64	8	66	Wind	D, S			
A. T. McGee	4	21	26	1872?	Bored, 6 inches	60	10	70	Hand	D			
W. H. Vaughan	32	20	26	1905	Bored, 7 inches	63	18		Gas	I	50		
C. J. Martin	6	21	26		Bored, 3 inches	30	15	69	Hand	D			
H. Hunsaker	25	20	25		Dug		13		Horse, wind	S			85.00
Stadmiller & Rising	2	21	25		Bored, 5 inches	41	12	69	Hand	D, S		20	4.50
Mr. Morris	34	20	25		do	30	12	69	do	D		15	4.50
Mr. Crabtree	20	20	25		do		10	71	Wind	D, S			50.00
J. M. Estes	20	20	25	1893	do	85	12?	70	Hand	D, S		47	4.50
J. T. Turner	19	20	25	1897	Bored, 7 inches	90	8		Wind, horse	D, S		60	195.00
J. H. Absher	19	20	25		Bored, 4 inches	30	7		Wind	D, S		15	50.00

Wm. Carpenter	18	20	25	1905	Bored, 5 inches	35	7.5		Hand	D, S		17	5.00
J. B. Walker	13	20	24		do	30	6	69	do	D, S		15	4.00
U. S. Experiment Station	14	20	24	1901	Bored, 10 inches	76	11		Gas	I	17	76	300.00
				1888	do	56	10		Horse	I	8	56	175.00
James Turner	4	20	24		Bored, 7 inches	60	11		Gas	S		35	240.00
James Hinton	10	20	24		Bored, 8 inches	60	12		do	I		45	250.00
J. H. McDonald	15	20	24	1889?	Bored, 5 inches	40	15?	70	Hand	D, S		20	4.00
P. Williams	15	20	24		do		10	70	Wind	D, S			75.00
Henry Heidsick	22	20	24		do	30	10	70	Hand	D, S		15	4.00
John Sobrest	23	20	24	1885	do	34	8	69	do	D, S		15	4.00
S. E. Wharton	16	20	24	1904	Bored, 10 inches	250	9.5		Gas	I	64	600	1,645.00
Mrs. J. M. Slinkard	26	20	24	1898	Bored, 8 inches	40	9		do	D, S		25	300.00
Van Lowman	27	20	24	1894	Bored, 6 inches	30	9	66	Hand	D, S		15	4.00
J. H. McFarland	27	20	24		do	80	9		Gas			280	
Do	27	20	24		do	60	9						
M. R. Lopes	27	20	24		Bored, 8 inches	48	8	67	Horse	D, S		35	15.00
J. H. McFarland	27	20	24	1891	Bored, 6 inches	52	10	66	Wind	D, S		50	75.00
Dr. Lewis	34	20	24		Bored, 10 inches		0	80	Artesian	I	a10		
H. H. Russell	34	20	24	1893	Bored, 5 inches	44	8	70	Wind	D, S		20	50.00
Henry Beatty	34	20	24		do	46	8.5	69	do	D, S		25	50.00
Sarah Phillips	32	20	24		Bored, 7 inches	1,000	0	72	Artesian	S	1		
Do	32	20	24		do		0	72	do	I	9		
California Savings & Loan Society	31	20	24		do		0	71	do	I	2		
R. Jones	30	20	24	1885	Bored, 6 inches	500	0	75	do	I, S	4		
W. A. Bailey	20	20	24	1902	Bored, 5 inches	75	9	68	Wind	D, S		37.50	50.00
O. W. Griffith	18	20	24	1899	do	80		69	Hand, wind	D, S		40	75.00
J. F. Haskell	19	20	24		do	23	10	72	Wind	D, S		10	75.00
B. Harrison	19	20	24		Bored, 7 inches		0	72	Artesian	I	9		
Page & Monteagle	13	20	23		do		0		do	I	a2		
J. Haskell	24	20	23		do	580?	0	71	do	I, S	Small.	1,000	
J. F. Chinn	25	20	23	1895	Bored, 4 inches	60	9	72	Wind	D, S		30	73.00
A. F. Stowe	25	20	23	1884	Bored, 8 inches	640	0	76	Artesian	I	11		
Page & Monteagle	14	20	23		do		0	74	do	I	6		
M. A. Quell	14	20	23		do		0	72	do	I	4		
John Crawford	26	20	23	1888?	Bored, 7 inches	400	0	72	do		Small.		
F. C. Hough	25	20	23		Bored, 9 inches	787	0	76	do	I	24		
Mrs. Trefry	26	20	23		Bored, 7 inches	300?	0	73	do	I	5		
P. F. Wood	35	20	23	1885	do	600	0	74	do		48		
Do	35	20	23		do	600	0		do	I	a30		
S. E. Hoffman	34	20	23	1890	Bored, 8 inches	500	0	73	do	D, S	Small.	1,000	
Do	34	20	23	1890	Bored, 9 inches	719	0		do	I	50	1,900	
S. F. Leckert	15	20	23		Bored, 8 inches	350?	0	73	do	S	2		
J. Huniston	15	20	23	1900	Bored, 10 inches	130	10		Gas	I	88	165	1,100.00
Do	15	20	23		Bored, 5 inches	65	9		Wind	D, S		35	75.00
G. W. Gibson	22	20	23	1889?	Bored, 9 inches	418	0	73	Artesian	I, D, S	5	756	
Henry Girdlestone	22	20	23		Bored, 7 inches		0	74	do	I	6		
Henry Bertch	21	20	23	1903	Bored, 5 inches	60	12	70	Wind	D, S		30	75.00
Mrs. E. E. Beal	21	20	23	1899	Bored, 12 inches	140	10		Steam	I		180	220.00
Geo. H. Castle	21	20	23	1904	Bored, 10 inches	102	10		Gas	I		80	120.00
San Francisco Savings Union	28	20	23		Bored, 7 inches		0	72	Artesian	S	3		
Do	28	20	23	1882	do	521	0	74	do	D, S, I	7		

a Yield estimated or statement of owner taken.

b Three wells.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
Wallace Bros.	32	20	23		Bored, 8 inches	530	0	74	Artesian	I	5	$600	
J. M. Sage	32	20	23	1903	Bored, 7 inches	53	10		Horse	I		100	$650.00
San Francisco Savings Union	32	20	23		Bored, 10 inches	800	0	75	Artesian	I	29		
Mr. Whitney	32	20	23	1904	Bored, 14 inches	175	8		Steam		*a* 222	350	5,000.00
Do	32	20	23	1904	Bored, 10 inches	868	0	76	Artesian	I	24	2,300	
H. B. Congdon	4	21	23	1888	Bored, 8 inches	35	15	70	Wind	S		35	50.00
F. W. Pursell	8	21	23	1905	Bored, 10 inches	954	0	78	Artesian	I	40	2,500	
Artesia school district	8	21	23		Bored, 5 inches	42	11	70	Wind	D		20	50.00
Mr. Anderson	3	21	23	1890	Bored, 8 inches	900	0	75	Artesian	I	42	2,000?	
W. F. White	3	21	23		do	750	0	74	do	I	24		
J. R. Hascoe	10	21	23	1897	do	800	0	74	do	I	20		
H. Kaiser	10	21	23	1887	do	778	0	75	do	I	38	2,000	
Chas. Blaswick	10	21	23		Bored, 7 inches	+500	0	74	do	I	4		
J. & M. B. LaMarche	1	21	23	1882	do	390	0	71	do	I, S, D	4		
Do	6	21	24		do		0	70	do	I, S	8		
Do	5	21	24		Bored, 12 inches		0	70	do	I	9		
W. Williams	8	21	24		Bored, 8 inches	38	10	70	Hand	S		25	4.00
Do	8	21	24		Bored, 7 inches		0	74	Artesian	I	4		
Mrs. Smith	4	21	24		do		0	72	do	S, D	Small.		
J. Goldman & Co.	17	21	24		do	41	9	69	Hand	S		25	4.00
San Francisco Savings Union	16	21	24		do		0	74	Artesian	I	15		
E. Lathrop	10	21	24		Bored, 8 inches	51	18	70	Wind	S		40	50.00
D. B. Moore	15	21	24		Bored, 7 inches		0	70	Artesian	I	7		
Thomas Blades	35	20	24		Bored, 5 inches	26	3	66	Hand	D		15	4.00
A. J. McKay	1	21	24		do	50	12?	70	do	D, S		25	4.00
Wm. James	11	21	24	1884	Bored, 6 inches	60	10		Horse	D, S		30	20.00
Dr. Wilson	7	21	25		Bored, 10 inches		0		Artesian, gas	D, S	Small.		
M. M. Janes	12	21	24		Bored, 5 inches	54	10	67	Wind	D, S		30	75.00
R. C. Clark	18	21	25	1887	Bored, 7 inches	51	14		do	D, S		50	75.00
T. J. Janes	14	21	24	1882	Bored, 8 inches	400	0		Artesian			621	
Sisson, Crocker & Co.	8	21	25	1880	do	35	12		Wind	D, S		35	50.00
J. S. Futrell	9	21	25	1895	Bored, 5 inches	50	12	68	Wind, horse	D, S		40	65.00
W. Coughran	10	21	25	1891	Bored, 7 inches	60	12	69	Horse	D, S		40	50.00
Dresser Bros.	17	21	25	1898	Bored, 8 inches	121	14	}	Steam	I	*a* 122	90	1,000.00
Do	17	21	25	1898	do	56	14	}					
B. W. Blankenship	16	21	25	1890	Bored, 6 inches	28	10	65	Hand	D		15	4.00
Do	16	21	25	1900	Bored, 8 inches	60	16	}	Gas	I	*a* 100	130	1,100.00
Do	16	21	25	1900	do	84	16	}					

Do	16	21	25	1890	Bored, 5 inches	60?	12	68	Wind	D, S		30	50.00
Do	15	21	25		do	29	13	69	do	D, S		15	50.00
John Ruppenthall	3	21	25		Bored, 8 inches		12		Horse	S			50.00
Sarope Gegargeion	11	21	25		Bored, 5 inches	21	12		Wind	D, S		10	50.00
P. N. Blankenship	10	21	25	1880	do	60	12	66	do	S		60	50.00
Linder Hardware Co	14	21	25	1898	Bored, 8 inches	26	15?	67	Hand	S		20	4.00
J. R. Blankenship	15	21	25		Bored, 5 inches	24	11	69	Wind	D, S		12	50.00
Louis Jager	22	21	25	1891	Bored, 6 inches	40	12	70	do	D, S		40	50.00
J. W. Martin	23	21	25	1905	Bored, 8 inches	60	13		Steam	I	180	50	1,000.00
B. F. Vaughn	13	21	25		Bored, 6 inches	75	12	68	Hand	D, S		40	4.00
Bennett Rising	11	21	25		Bored, 5 inches	28	11.5	68	do	S		15	4.00
H. H. Hannaford	2	21	25	1870	Bored, 8 inches	48	15	68	Wind	D, S		50	50.00
E. & L. Cornell	13	21	25		Bored, 5 inches	26	9	66	Hand	D		15	4.00
Bigham estate	24	21	25	1888	Bored, 6 inches	32	7	70	Wind	D, S		18	100.00
R. H. Allen	8	21	26	1880	do	33	6	68	do	D, S			
T. P. Carlisle	18	21	26		Bored, 7 inches	38	6	70	Hand	D			
W. W. Futrell	20	21	26	1893	Bored, 3 inches	31	7	70	do	D			
J. B. Monroe	17	21	26	1895	Bored, 5 inches	44	6	69	Wind	D			
C. Otto	16	21	26	1891	do	40	6	68	Hand	D			
J. Vossler	21	21	26	1888	Bored, 6 inches	52	7	69	do	S			
J. Vincent	20	21	26		Bored, 5 inches	38	6	70	do	D, S			
C. A. Ball	22	21	26	1894	Bored, 8 inches	30	7	68	Hand	D			
J. Maples	14	21	26	1895	Bored, 5 inches	52	6	69	Wind	D, S			
L. Griffin	23	21	26		Bored, 4 inches	40	6		do	D, S			
R. H. Dickey	23	21	26	1890	Bored, 5 inches	45	6	69	Hand	D			
D. Udell	19	21	27	1892	do	55	9	69	Wind	D, S			
J. L. Miner	30	21	27	1896	Bored, 7 inches	49	9	67	do			50	
B. Stadtmiller	30	21	27	1890	Bored, 6 inches	53	6	65	Hand	D, S			
H. Quinn	31	21	27		do	47	6	66	do	D			
G. Caldwell	29	21	27	1898	Bored, 5 inches	52	5	69	do	D			
Burton school district	28	21	27		do	54	6	68	do	D			
M. A. Williams	33	21	27	1898	do	40		68	do	D			
G. Gregory	28	21	27	1898	do	44	7	69	do	D			
W. Atkin	34	21	27	1892	do	42	8	68	Wind	D, S		30	35.00
City of Portersville[b]	25	21	27	{1901 1904}	Bored, 12 inches	200	25	71	Electric	D, S	122		
A. G. Schulz	25	21	27	1898	Bored, 11 inches	170	26	71	Gas	I		250	
Mrs. W. M. Henry	25	21	27	1897	Bored, 12 inches	152	29		Steam		30		
G. W. Smith	30	21	28	1900	Bored, 10 inches	85	12		Gas	I	12		
M. Davidson	30	21	28	1902	Bored, 12 inches	130	10	70	Electric	I	a 55	400	1,600.00
Do	29	21	28	1902	do	102	27	71	do	I	43		1,600.00
Rosedale Water Co	3	22	28	1897	Dug	23	6	70	do	I	43	150	1,000.00
C. D. Boydston	3	22	28	1904	Bored, 12 inches	190	22	72	do	I	a 70	600	4,000.00
Do	10	22	28	1904	do	100	24	71	(c)	S	(c)	250	
Mrs. R. A. Henderson[d]	4	22	28	1904	do	60	12	70	Electric	I	a 60		
W. H. McCain	6	22	28	1901	Bored, 10 inches	120	65		do	I	a 8	240	600.00
Frame Bros	1	22	27	1901	do	144	43	74	do	I	16		
C. Talbott	1	22	27	1902	Bored, 12 inches	194	8		do	I	a 18	270	1,000.00
P. Ting	1	22	27	1901	Bored, 10 inches	160	38	74	do	I	9	500	600.00
C. Sullivan	12	22	27	1904	Bored, 12 inches	205	63	72	do	I	a 37		

a Yield estimated or statement of owner taken.
b Two wells.
c Tapped below surface; flow 13 miner's inches.
d Five wells.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
C. J. Swartz	10	22	27	1901	Bored, 6 inches	60	33	73	Wind	D, S		$42	$60.00
C. Bastain	9	22	27		do	51	30	72	do	D, S			
J. W. Hockett	34	21	27	1895	Bored, 2 inches	36	7	68	Hand	D			
G. Anthony	4	22	27	1890	Bored, 6 inches	35	9	69	Wind	D, S			
G. B. Moore	8	22	27		do	38	14	69	do	D, S			
V. A. Stewart	7	22	27	1887	do	47	16	69	do	D, S			
Mrs. M. Florey	31	21	27	1884	Bored, 5 inches	45	6	67	Hand	D			
C. Bour	31	21	27	1896	do	34	6	69	Wind	D, S			
F. W. Howell	6	22	27		do	38	8	70	do	D, S			
U. M. Ferguson	1	22	26	1904	Bored, 12 inches	52	9	70	Gas	I			
J. M. Ferguson	2	22	26		Bored, 5 inches	34	9	69	Hand	D			
J. E. Henderson	25	21	26	1885	Bored, 7 inches	60	6	67	Wind	D, S			
E. R. Buxton	26	21	26		Bored, 4 inches	64	7	70	do	D		65	
S. Vincent	26	21	26	1902	do	28	8	71	do	S		18	
S. J. Vincent	27	21	26	1886	Bored, 5 inches	75	8		do	S		54	
H. Quinn	27	21	26		do	44	8	70	do	D, S			
F. Carlisle	27	21	26	1890	do	25	8	70	do	D		15	
A. E. Scruggs	28	21	26	1892	Bored, 6 inches	64	9	71	Horse	D, S		47	
U. F. Woods	35	21	26	1905	Bored, 16 inches	170	16	69					
V. A. Stewart	34	21	26	1890	Bored, 5 inches	38	10	70	Wind	D, S		30	
M. Dale	4	22	26		Bored, 4 inches	40	13	69	do	D, S			
M. Gilligan	29	21	26	1895	Bored, 6 inches	70	10		do	D, S			
Do	29	21	26	1895	do	75	10		Hand	D		75	
Do	30	21	26	1885	do	75	10	70	do	D		75	
G. J. Herndon	32	21	26		Bored, 7 inches	33	13	70	do	S			
G. J. Martin	32	21	26		Bored, 6 inches	30	11	70	Wind	S			
T. J. Allen	24	21	25	1893	do	75	10	68	Hand	D		40	4.00
E. Z. Callison	26	21	25	1870	Bored, 8 inches	70	10	65	do	D, S		100	25.00
L. N. Callison	2	22	25	1885	Bored, 5 inches	60	20	72	do	S, D		45	12.00
Mrs. G. Montgomery	4	22	25	1887	Bored, 8 inches	60	18	70	Horse	D, S		33	12.00
Mrs. A. B. McNeil	4	22	25	1895	Bored, 6 inches	60	23		Wind	D, S		35	50.00
W. H. Crowley	5	22	25	1904	Bored, 10 inches	72	25		Gas	I	*a* 300	72	1,700.00
Do	5	22	25		Bored, 8 inches	76	22	72	Wind	D, S		60	75.00
Mrs. A. Treybal	5	22	25		Bored, 7 inches	34	24	70	do	D, S		20	75.00
John Clark	32	21	25		do	35	19	70	do	S		20	50.00
G. E. Gibb	30	21	25	1905	Bored, 8 inches	67	15	70	Horse	I		58	80.00
Dresser & Smith	19	21	25	1904	Bored, 12 inches	92	13		Gas	I	*a* 100	150	1,385.00
T. J. Janes	24	21	24		Bored, 7 inches	50	15	68	Wind	S		30	4.00

F. Jordan	24	21	24	1885	Bored, 4 inches	255	16.5		do	D, S		13	50.00
E. W. Bagby	25	21	24	1899	Bored, 10 inches	80	16		Gas	I	a 150	80	1,120.00
Mrs. A. Treybal	31	21	25	1888	Bored, 5 inches	93		69	Hand	D, S		45	4.00
Mrs. N. G. Rice	6	22	25	1902	Bored, 8 inches	60	23		Wind	D, S		80	75.00
H. J. Hawkins	2	22	24		do		1		do	S			50.00
Mrs. L. L. Creech	26	21	24	1887	Bored, 7 inches	600	0	72	Artesian	I	2	1,000	
L. B. Retherford	24	21	24	1899	Bored, 5 inches	29	14	69	Hand	D		32	4.00
Mrs. J. Mead	23	21	24	1884?	Bored, 7 inches		0	70	Artesian	I	4	800	
Chas. Dresser	26	21	24		do	33	11	67	Horse	D, S		20	40.00
T. J. Mitchell	27	21	24	1882	do	355	0	70	Artesian	I, D	12		
F. M. Creech	34	21	24	1896	Bored, 8 inches	64	14		Gas	I		90	1,200.00
Do	34	21	24	1896	do	72	14						
School district	3	22	24		Bored, 7 inches	52	16		Wind	D		35	50.00
S. A. Nickols	2	22	24	1893	do	50	17	69	do	S		60	50.00
San Francisco Savings Union	2	22	24		do		0	74	Artesian	I	2		
T. J. Mitchell	3	22	24	1889	do	825	0		do	I	12	2,200	
Mrs. Elsie Beckwith	4	22	24	1883	do	410	0	73	do	I, D, S	7	414	
H. H. Beckwith	4	22	24	1890?	Bored, 8 inches	600	0	72	do	I	12	900	
Wm. Swall	23	21	24		do	500	0	70	do	I	5		
Mrs. Smith	28	21	24	1880	Bored, 7 inches	400	0	72	do	I	7	600	
Wm. Swall	27	21	24	1905	Bored, 10 inches	87	14		Steam	I	a 150	50	2,300.00
B. Gulley	22	21	24	1875	Dug, 4 by 4 feet	20	15	68	Wind	S		20	30.00
Wm. Swall	28	21	24		Bored, 10 inches	350	0	70	Artesian	I	11		
Elk Bayou school district	29	21	24		Bored, 5 inches	50	12		Wind	D		30	50.00
Evans Bros	20	21	24	1891	do	50	12		do	N		25	
J. H. Finney	29	21	24	1883	Bored, 7 inches	500	0	72	Artesian	I	9	1,000	
Do	29	21	24		Bored, 6 inches	50	12		Wind	S		25	50.00
W. J. Estes	32	21	24	1880	Bored, 5 inches	30	11		do	D, S		15	25.00
D. K. Berry	31	21	24	1874	Bored, 7 inches	30	17	69	do	D, S		25	25.00
Do	31	21	24	1885	Bored, 8 inches	630	0	71	Artesian	I	5	1,200	
M. A. Edgar	6	22	24		do		0	73	do	I	6		
Cosmos Land & Water Co	5	22	23		Bored, 7 inches	34	14.5		Horse	I		100	125.00
Geo. Harrison	31	21	23		Bored, 8 inches	350	0	74	Artesian	D, S	a 2		
C. H. Sherwin	7	22	23	1898	Bored, 2 inches		0	69	do	D, S	Small.	174	
A. V. Taylor	17	22	23		Bored, 12 inches	815	0	76	do	I	30		
Do	17	22	23		Bored, 8 inches	918	0	78	do	D, S, I	78		
Mr. Quimby	19	22	23		Bored		0	74	do	D, I, S	a 5		
S. Mitchell	21	22	23		Bored, 7 inches	800	0	78	do	I, D, S	56		
F. A. Thompson	30	22	23	1893	Bored, 9 inches	1,000	0	81	do	I, S, D	76	3,000	
Do	30	22	23	1905	Bored, 4½ inches	1,200	0	77	do	I	30	1,080	
F. M. Parrish	29	22	23		Bored, 10 inches	700	1	68	Hand	D, S		1,050	10.00
C. Curry	29	22	23		Bored, 7 inches		0	72	Artesian	D, S	2		
A. Watts	29	22	23		Bored, 9 inches	830	0	76	do	I			
H. W. Butcher	27	22	23		Bored, 12 inches	50	10	68	Wind	D, S		50	275.00
J. Goldman	8	22	24		Bored, 5 inches	56	12		Not raised	N		55	
Seth Kirby	8	22	24	1886	Bored, 9 inches	606	0	70	Artesian	I	16	1,300	
Lakeview school district	8	22	24	1884	Bored, 5 inches	50	11		Wind	D		50	40.00
Mrs. Elsie Beckwith	8	22	24		do	46	12		do	S		45	50.00
F. J. Hesse	20	22	24	1887	Bored, 8 inches	606	0	70	Artesian	I	24	1,240	
Mr. Mansky	9	22	24		do		0	69	do	I	24		

a Yield estimated or statement of owner taken.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Station.	Township south.	Range east.										
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
F. J. Crane	10	22	24	1884	Bored, 5 inches	435	0	69	Artesian	S	......	......	......
Robert Doran	10	23	24	1884	Bored, 8 inches	480	0	69	do	I	13	$900	......
A. D. Evans	10	22	24	......	do	68 76	18 18	67 67	Steam	I	*a* 133	150	$1,400.00
Mrs. C. Ranger	22	22	24	1887?	do	600	0	70	Artesian	I	16	......	......
Do	22	22	24	1893	Bored, 14 inches	1,400	0	71	do	I	5	6,000	......
H. C. Grigsby	22	22	24	1885	Bored, 7 inches	450	0	69	do	I	3	......	......
Fred Hesse	26	22	24	......	Bored, 8 inches	+400	0	68	do	I	11	900	......
R. H. Copeland	26	22	24	1905	do	78 102	15 15	......	Steam	I	......	200	210.00
Frank Laughlin	24	22	24	1896?	do	500	0	70	Artesian	I	18	......	......
J. Ranger	24	22	24	......	Bored, 7 inches	......	0	69	do	S	3	......	......
Wm. Budd	23	22	24	......	Bored, 10 inches	1,100	0	70	do	I	36	2,700	......
J. J. Ryan	13	22	24	1886	Bored, 9 inches	1,043	0	72	do	I	3	......	......
B. C. Treefry estate	18	22	25	......	Bored, 7 inches	400	3	......	Not raised	N	......	......	......
Do	14	22	24	......	do	......	1	......	do	N	......	......	......
A. N. Towne Co	12	22	24	......	do	......	0	72	Artesian	S	Small.	......	......
Do	7	22	25	......	Bored, 8 inches	400?	3	......	Hand	N	......	......	5.00
W. J. Coles	20	22	25	1887	Bored, 5 inches	65	16	......	Wind	D, S	......	40	100.00
Robert McDaniel	22	22	25	1905	do	26	18	67	do	S	......	15	65.00
W. J. Browning	10	22	25	1901	Bored, 14 inches	84	32	......	Steam?	I	......	......	......
S. D. Luck	23	22	25	1904	Bored, 5 inches	31	15	......	Wind	I	......	29	15.00
S. B. Garrett	4	22	26	1902	Bored, 6 inches	30	14	70	Hand	D	......	......	......
J. Murphy	4	22	26	......	Bored, 4 inches	29	14	70	do	D	......	......	......
E. A. May	10	22	26	......	Bored, 5 inches	45	12	71	Wind	D	......	......	......
E. Saak	11	22	26	......	do	31	15	71	do	S	......	20	......
E. L. Cloer	15	22	26	1904	Bored, 10 inches	48	16	......	Gas	I	60	......	......
J. Fine	22	22	26	......	Bored, 5 inches	54	17	71	Wind	D, S	......	40	......
J. Vincent	21	22	26	......	Bored, 6 inches	35	18	......	do	S	......	......	......
C. N. Thomas	14	22	26	1899	Bored, 5 inches	42	15	71	do	D, S	......	......	......
A. Hayes	12	22	26	......	Bored, 6 inches	50	22	73	do	D, S	......	......	......
E. L. Cloer	24	22	26	......	Bored, 5 inches	43	21	69	do	D, S	......	......	......
Mr. Chinn	17	22	27	1905	Bored, 7 inches	48	40	......	Not raised	N	......	......	......
Hope school district	16	22	27	1890	Bored, 8 inches	52	40	......	Wind	D	......	......	......
J. Kambich	11	22	27	1888	Bored, 6 inches	61	53	71	do	D, S	......	......	......
D. Abbott	14	22	27	1893	do	+100	72	72	do	D	......	......	......
D. Sturm	12	22	27	1903	Bored, 12 inches	240	60	73	Electric	I	*a* 18	600	1,400.00
A. Sauerwein	18	22	28	1904	do	197	58	71	do	I	14	500	......

M. C. Thompson	18	22	28		Bored, 6 inches	140	67	69	Wind	D, S			
H. Mentz	20	22	28		Bored, 7 inches	112	32	69	Horse	D, S			
A. Konda	4	23	28	1902	do	200	120		do	D, S			
L. W. Howeth	26	23	28		Dug, 4 by 4 feet	53	38		Wind	D			
J. B. Dennis	30	23	28	1893	Bored, 6 inches	98	64	71	do	D, S			
Hall, Brownell & Myers	23	23	27	1889	Bored, 7 inches	150	105		Horse	S			
Higgins & Tyler	14	23	27		do	126	84		Wind	D, S			
M. Davidson	2	23	27		Bored, 6 inches	98	88	70	do	D, S			
Salem school district	3	23	27		do	110	81	70	do	D			
J. F. Blair	4	23	27	1886	Bored	92	90	72	Horse	D, S			
J. E. Porch	8	23	27	1889	Bored, 7 inches	100	87	71	Wind	D, S			
R. Porch	8	23	27	1890	do	104	89	71	do	D, S			
Mrs. M. S. McCapes	6	23	27	1887	Bored, 6 inches	84	56	71	Wind and hand	D, S			
M. E. Galbraith	6	23	27		do	72	50	71	Wind	D, S			
A. J. Salladay	12	23	26		Bored, 7 inches	79	51		do	D, S			
Tulare County	30	22	27	1900	Bored	35	23	68	Hand	S		35	
J. McNeil	26	22	26	1885	Bored, 6 inches		25		Wind	D, S			
L. Shoenfeld	27	22	26		Bored, 5 inches	50	17	69	do	D, S			
M. Cottle	28	22	26	1887	do	64	18	70	do	D, S		65	
J. Vincent	32	22	26		Bored, 6 inches	74	18		do	S		75	
J. C. Tilton	4	23	26	1902	Bored	65	35	68	do	D, S		45	80.00
W. W. Salladay	10	23	26	1885	Bored, 5 inches	50	35	69	do	D, S			
D. Williams	8	23	26	1887	Bored, 6 inches	30	27	72	do	D		25	70.00
S. I. Vincent	6	22	26	1891	do	72	19	70	do	D, S			
E. N. Brushwood	12	23	26	1893	Bored, 8 inches	90	20	67	Horse	S			
G. W. Doran	10	23	25	1885	Bored, 7 inches	80	18	71	Wind	D, S			
J. Gable	2	23	25		Bored, 4 inches	62	26	67	do	D, S			
E. J. Elster	34	22	25	1885	do	40	24	70	do	D			
Wm. Gable	35	22	25	1890	Bored, 8 inches	26	18		do			25	40.00
J. T. Luck	34	22	25	1887	Bored, 5 inches	28	16		do	S		28	65.00
J. M. Failing	34	22	25	1901	Bored, 7 inches	60	16		Horse	D, S		50	100.00
J. E. Failing	34	22	25	1891	Bored, 5 inches	40	16		Wind	S		30	65.00
R. T. Priest	3	23	25		Bored, 8 inches	600		66	do	S			
Do	3	23	25	1882	do	680		76	do	S			
G. W. Smith	10	23	25	1892	Bored, 7 inches	99	24	70	do	S, D		80	150.00
S. S. Huston	14	23	25	1887	do		16	69	do	S			
H. E. Phillips	14	23	25		do		16		Not raised	N			
J. A. Peck	30	22	25		Bored, 8 inches		0	72	Artesian	I	a 5		
D. F. Retherford	29	22	25	1886	do	24	18		Wind	D, S		25	40.00
W. A. Lythe	32	22	25		do	750?	0	72	Artesian	I	Small.	1,600	
J. W. Harper	32	22	25		do		0	78	do	S	9		
P. Slowey	7	23	25	1890	do	500	0	78	do	I	8		
Mrs. L. Hefty	7	23	25	1890	Bored, 9 inches	800	0	77	do	I	3	800	
N. C. Cross	8	23	25	1903	Bored, 6 inches	30	16	64	Wind	D, S		30	20.00
W. B. Bradbury	8	23	25	1895	Bored, 8 inches	1,387	0	79	Artesian	I	40		
J. Manuel	18	23	25	1883	Bored, 9 inches	500	0	76	do	S	3		
D. Abrate	18	23	25	1883	Bored, 6 inches	14	12	63	Hand	D			
W. Dougherty	14	23	24	1903	Bored, 7 inches	100	16	65	Wind	D, S			
Towne ranch	11	23	24		Bored, 9 inches	1,142	0	80	Artesian	I			
Do	11	23	24		do	815	0	70	do	I			
Do	11	23	24		do	1,000	0	78	do	I			

a Yield estimated or statement of owner taken.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
Mrs. M. H. Smith	2	23	24	1883	Bored, 8 inches	550	0	74	Artesian	I	23	$1,060	
L. E. Smith	36	22	24	1904	Bored, 4 inches	80	16	70	Gas	I	50	200	$1,600.00
San Francisco Savings Union	36	22	24		Bored, 9 inches	+700	0	70	Artesian	I			
Mrs. A. J. Merchant	35	22	24	1888	Bored, 8 inches	900	0	70	do	I	11	3,000	
J. S. Copland	26	22	24		Bored, 5 inches	28	12		Horse	D, S		30	50.00
W. H. Howard	34	22	24	1888	Bored, 9 inches	582	0	75	Artesian	I	18	1,200	
San Francisco Loan & Savings Bank	3	23	24	1883	Bored, 8 inches	600	0	74	do	S	32		
Do	3	23	24	1891	Bored, 9 inches	+800	0	78	do	I	58		
Do	33	22	24	1887	do	+600	0	78	do	S, I	58		
J. Black	9	23	24	1890	Bored, 10 inches	1,000	0	78	do	I, S, D	76	3,000	
Do	16	23	24	1890	do	1,100	0	80	do	S	205	4,000	
L. P. Chittenden	7	23	24	1890	do	+700	0	77	do	I	52		
Do	7	23	24	1890	do	+700	0	78	do	I	58		
M. C. Meeker	5	23	24		Bored, 5 inches	+500	0	76	do	S			
L. P. Chittenden	6	23	24		do		0	77	do	S	13		
W. H. Harp	3	23	23	1905	Hydraulic, 5⅝ inches.	1,103	0	78	do	I	42		
P. D. Brudaker	3	23	23	1904	Hydraulic, 4 inches	1,025	0	78	do	I	19	800	
Do	3	23	23	1904	Bored, 2 inches	355	0	70	do	D	Small.	160	
W. H. Harp	3	23	23	1905	Hydraulic, 4 inches	345	0	71	do	D, S	Small.		
T. G. McGinnis	5	23	23		Hydraulic, 2 inches		0	72	do	S	Small.		
W. A. Sage	8	23	23		do		0	70	do	D, S			
E. L. Kauffman	9	24	23		Bored, 8 inches		0	76	do	I, D, S			
L. G. Grosse	21	24	23		Bored		0		do	S	Small.		
Crocker estate	32	24	24		Bored, 10 inches		0	70	do	N	134		
Frank Smith	28	24	23		Bored, 8 inches		0	70	do	N	Small.		
Mr. McCord	29	24	24		do		0	72	do	I	22		
W. E. Brown	28	24	24		do		0		do	N	*a* 8		
D. T. Curtis	22	24	24		Bored, 6 inches		0	71	do	N	Small.		
D. R. Hughes	28	23	25		Bored, 8 inches	68	30?		Wind	S		70	125.00
J. D. Fraser	32	23	25		Bored, 7 inches	50	14		do	D, S		50	100.00
	33	23	25		Bored, 10 inches	1,300	0	75	Artesian	I	22		
W. O. Goldman	34	23	25	1893	Bored, 7 inches	+60	21	60	Wind	D			
S. S. Hessa	34	23	25	1886	do	42	25	58	do	D		42	95.00
L. Bearce	26	23	25		Bored, 10 inches	106	27	69	} Gas	I	88	320	1,900.00
Do	26	23	25		do	93	27	69					
W. H. Haroldson	2	24	25	1893	Bored, 7 inches	55	35		Not raised	N			
J. Martens	2	24	25	1903	do	58	40		do	N			

W. H. Haroldson	2	24	25	1893	Bored, 9 inches	70	40		do	N			
Do	10	24	25	1885	Bored, 7 inches	50	30		Wind	D, S		50	165.00
J. D. Fraser	4	24	25		Bored, 5 inches	50	15		do	S		50	45.00
M. L. Nichols	22	24	25	1890?	Bored, 8 inches	60	25		Gas	I	88	60	1,000.00
C. W. Turner	28	24	25	1900	Bored, 10 inches	75	20		do	I	44		b 800.00
A. Panero	26	24	25	1890	Bored, 6 inches	89	40	68	Wind				
J. W. Hamilton	24	24	25		Bored, 8 inches	70	40	70	do				
Chas. Rieck	24	24	25	1887	Bored, 7 inches	57	45		do	S		60	90.00
Do	18	24	26	1882?	Bored, 5 inches	56	52		do	D, S		55	90.00
Do	18	24	26	1887	Bored, 7 inches	71	61		Not raised	N		70	
Mr. Pinney	18	24	26		do	62	52		Wind	N		60	150.00
Charles Rieck	6	24	26		Bored, 8 inches	62?	51		do	S			125.00
Frank Schlitz	6	24	26	1902	Bored, 10 inches	75	50	65	Gas	I	100	300	1,700.00
L. Bearce	6	24	26	1887	Bored, 7 inches	54	35	62	Wind	D, S			125.00
Do	5	24	26		do	60	45		Hand	S			
H. B. Razey	20	23	26	1889	do	60	40	68	Wind	D, S			
J. Jackson	22	23	26	1887	Bored, 5 inches	90	80	66	do	D, S		60	
A. Child	2	24	26	1887	Bored, 7 inches	111	100	56	do	D, S		113	230.00
Mr. Comstock	35	23	26	1890	do	115	100	58	do	S			
Lockridge & Turner	34	23	26	1904	do	100	80	63	do			100	
C. L. Pinney	8	24	26	1888	Bored, 8 inches	78	67		do	D, S		80	150.00
W. H. Haroldson	9	24	26		do	120	67		do	S		120	
J. H. Cox	20	24	26	1889	Bored, 6 inches	80	60		do	D, S		80	180.00
Wildflower school district	16	24	26	1890	Bored, 7 inches	100	85		do	D		100	75.00
A. Sheppard	20	24	26	1904	do	82	56	60	do	D, S		80	145.00
J. Cox	30	24	26	1895	do	100	60	65	do	D, S		100	75.00
Mrs. L. C. Martin	30	24	26	1887	do	100	74	60	do	D		75	100.00
P. Shanahan	30	24	26	1897	do	90	60	60	do	D		50	167.00
C. Willard	32	24	26	1894	Bored, 6 inches	118	89	58	do	D, S		80	155.00
J. Panetto	32	24	26	1885	do	110	100	61	do	D, S		85	
J. Hedrick	34	24	26	1890	Bored, 7 inches	140	130	64	do	D, S			
Mr. Reba	28	24	26		do	100	70		Not raised	N			
W. H. Haroldson	21	24	26		do	100	75		Horse	N			
B. Edwards	14	24	26	1887	do	100	96		do	D		100	75.00
W. H. Harrison	15	24	26	1901	Bored, 8 inches	114	100		do	S		80	50.00
Joe Fore	22	24	26		do	120	90		Wind	S		120	226.00
W. F. Burum	22	24	26	1887	do	100	92		do	D		100	226.00
P. F. McDevitt	26	24	26	1892	Bored, 7 inches	146	140	70	do	D, S		140	186.00
H. P. Burum	26	24	26	1888	do	164	158	74	do	D, S		100	115.00
Mr. Bryant	34	24	26	1885	do	147							
W. L. Smith	24	24	26			146	138		Wind, horse	S		150	175.00
W. H. Haroldson	11	24	26		Bored, 7 inches	140	120		Horse	D, S		140	100.00
W. E. Welch	12	24	26		do	146	122		Wind	D, S		171	229.00
B. McCracken	6	24	27	1887	Bored, 6 inches	155	140		do	S			
W. K. Braly	32	23	27	1886	do	162	140	68	do	D, S		150	270.00
A. Welch	28	23	27	1887	do	150	140	68	do	D, S			
F. M. Carlisle	28	23	27	1890	Bored, 7 inches	175	145	66	do	D			
Braly Bros	33	23	27	1887	do	160	140	67	do	S		150	
Do	34	23	27	1887	Bored, 6 inches	200	170		Not raised	N			
A. J. Hall	35	23	27	1898	Bored, 7 inches	250	196		Horse	S			

a Yield estimated or statement of owner taken.

b Cost of well and equipment combined.

TABLE 55.—*Records of wells in Tulare County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
W. L. Smith	4	24	27	....	Bored, 7 inches	130	120	62	Wind	D	....	$225	$150.00
E. Zimmerman	28	24	27	....	Bored, 8 inches	160	135	....	do	D, S	....	160	150.00
John Crangle	8	24	27	....	Bored, 7 inches	160	135	....	do	D, S	....	160	175.00
P. Phillips	29	24	27	1890	do	200	190	....	Wind, horse	S	....	....	....
Neil Beaton	28	24	27	....	do	244	190	....	Wind	D, S	....	350	225.00
John Collins	26	24	27	....	do	225	215	....	do	D, S	....	225	125.00
Mrs. E. Zimmerman	11	24	27	....	Bored, 8 inches	61	32	....	do	D, S	....	60	200.00
Do	11	24	27	....	do	71	29	....	Not raised	N	....	70	....
C. Menney	12	24	27	1890	....	40	8	....	Wind	D, S	....	....	....
H. C. Castor	12	24	27	1890	Bored, 8 inches	84	40	....	Horse	D, S	....	....	....
N. H. Kelly	12	24	27	1890	do	84	40	70	Wind	D, S	....	84	85.00
W. O. Todd	18	24	28	1875	Dug, 4 by 4 feet	18	14	....	Horse	S	....	50	50.00
J. Menney	8	24	28	....	Dug	20	9	....	do	D, S	....	....	....
Joseph Miller	4	24	28	1894	Bored, 8 inches	200	190	....	Wind	D	....	200	?200.00
Pacific Coast Oil Co	19	23	24	1904	Bored, 10 inches	726	0	....	Artesian	B	4	....	....

KINGS COUNTY.

GENERAL CONDITIONS.

The valley portion of Kings County includes the present and past Tulare Lake bottoms and the southern slope of the lower Kings River delta. Tulare basin is the lowest point in the southern section of the valley and is the area in which all surplus waters from Kings River southward accumulate. The flood waters of Kings River are divided on its delta, part of them flowing northward to join the San Joaquin drainage, while the other part flows into Tulare Lake. During years of low or moderate snowfall and rainfall in the Sierra, practically all the flow of Kern, Tule, Kaweah, and Kings rivers is used in irrigation, and there is but little excess to escape to the basin; but during years of heavy precipitation great volumes of water accumulate in the Tulare lowlands. This basin is very shallow. Its shores have gentle slopes, hence the area of the lake fluctuates widely with slight changes in the depth of the water in it. Since settlement began in the San Joaquin Valley it has had a complex history. What is known of its earlier history has been summarized by Grunsky.[1] That part of the following résumé which deals with conditions prior to 1897 is condensed from his account; the résumé of conditions since 1907 has been furnished by H. D. McGlashan, district engineer, U. S. Geological Survey.

Résumé of history of Tulare Lake.[2]

1853. High.
1853–1861. Subsidence; elevation of surface in 1861, 204 feet above sea level.
1861–1863. Rapid rise to the highest known stage, 220 feet above sea level, overflowing into San Joaquin River; area about 800 square miles.
1863–1867. Decline to about 208 or 209 feet above sea level.
1867–1868. Filled again to about 220 feet above sea level.
1872–1876. Fluctuated between 211 and 217 feet above sea level.
1876–1883. Decline to 192 feet above sea level; lowest stage then known.
1883–1897. Fluctuating; generally low.
1897–1905. Decline; practically dry in 1898; dry in autumn of 1905.
1905–1907. Rise; elevation of water surface in summer of 1907, 193 feet above sea level; area of water surface, November, 1907, 274 square miles.[3]
1907–1908. Depth gradually decreased from 14 feet in June, 1907, to 8.3 feet in December, 1908.
1909–1911. Gradual rise to depth of 13.4 feet in July, 1909; change in stage gradual to December, 1911, when depth was 10 feet.
1912–1913. Precipitation low. Depth gradually decreased to 1.5 feet in September, 1913.

[1] Grunsky, C. E., Irrigation near Bakersfield, Cal.: U. S. Geol. Survey Water-Supply Paper 17, pp. 16–17, 1898. Out of print; may be consulted in libraries.

[2] Elevation of bottom of lake, 179.1 feet above sea level.

[3] McGlashan, H. D., and Dean, H. J., Stream measurements in San Joaquin River basin: U. S. Geol. Survey Water-Supply Paper 299, p. 20, 1912.

A knowledge of the history of this lake makes clear the origin and character of the soils of all except the northern part of Kings County, where the alluvial-fan or "delta" conditions so general in San Joaquin Valley prevail.

Evidences of the former occupancy of the lowlands by the lake appear everywhere. Faintly marked sandy beaches encircle the depression at various elevations and over these beaches are strewn the shells of the mollusks that lived in the lake. In its lowest parts, dry and planted in grain in 1905, the fine sediments that settled in the lake bottom make a fertile alluvial soil.

It is to be presumed that the history of the lake for many centuries has been like that part of it which we know directly, i. e., that it has fluctuated in area and depth, occasionally drying out completely, then filling to the point of overflow. Under such conditions relatively little of the water which it has contained can have escaped by surface overflow; the greater part of it has evaporated or has been absorbed by the sands and silts of the lake bottom.

With the shrinking of the lake during the years preceding the inflow of 1906, its old floor was placed under cultivation and valuable crops of grain were produced. This successful grain culture proves the nonalkaline character of the present surface of the old lake bottom, but the saline waters yielded by numerous shallow flowing wells within it indicate the presence of alkali at slight depths. The few wells available as evidence in and about the borders of the old lake, however, indicate that deeper wells in some places obtain the better water.

FLOWING WELLS.

There are probably as yet less than 100 flowing wells in Kings County (77 were visited by Geological Survey representatives in 1905), yielding approximately 20 second-feet. Probably not more than one-third of the wells are used for irrigation, a large number of small-bore shallow wells being used for stock and for domestic supply. The northern part of the county, in the vicinity of Hanford, Armona, and Lemoore, is well supplied with surface water by the canal systems that head in Kings River, and is a most productive, thoroughly cultivated area. Ground waters are not needed and no serious attempt has been made to utilize them here.

In the vicinity of Corcoran, Waukena, and Angiola, however, a successful colony has been established that depends almost entirely upon ground waters. A number of deep wells have been put down to depths of 900 to 1,600 feet, which yield flowing waters in amounts ranging from 5 to 40 miner's inches. Shallow wells have also been bored and pumping plants have been installed over them. The tract includes about 30,000 acres, and alfalfa, cereals, sugar beets, dairy and garden products, and fruits are produced successfully.

Owner.	li-t...s).	Classification. Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.
J. E. Meadows	)	High	$Ca-SO_4$	Bad	Good.
Do	)	...do	$Na-SO_4$	Very bad	Do.
	;	Very high	...do	...do	Poor.
E. P. McAdams	;	Moderate	$Ca-CO_3$	Fair	Good.
F. Blakeley	7	High	$Na-SO_4$	Bad	Do.
W. D. Sprague	)	Moderate	$Na-CO_3$	Fair	Fair.
Rhodes estate	5	...do	...do	Bad	Poor.
R. W. Dougherty	4	...do	...do	Very bad	Do.
M. A. Heinlen	2	High	$Na-SO_4$	Bad	Good.
Do	2.8	...do	$Na-CO_3$	Very bad	Poor.
C. C. Friend	4	...do	...do	...do	Do.
	1.5	Very high	$Na-SO_4$	...do	Do.
W. N. Stratton	2.9	High	$Na-CO_3$	...do	Do.
J. F. Poole	4.2	...do	$Na-SO_4$	...do	Do.
C. E. Mort	3.8	...do	$Na-CO_3$	...do	Do.
Mrs. M. Dutra	)	Low	$Ca-CO_3$	Good	Good.
William Hogle	2	Moderate	$Na-CO_3$	Fair	Fair.
D. Ross	1	...do	...do	Bad	Do.
Ernest Howe	5	...do	...do	Fair	Do.
A. P. Redding	2	...do	...do	...do	Do.
W. S. Burr	3	...do	...do	Bad	Do.
Mrs. E. M. Killmer	3.6	High	...do	Very bad	Poor.
Dallas school district	2.3	...do	...do	...do	Do.
J. Martella	)	Moderate	...do	Fair	Fair.
Do	9	...do	$Na-Cl$	...do	Do.
	2.4	Very high	$Na-SO_4$	Very bad	Poor.
W. H. Thayer	5	Moderate	$Ca-CO_3$	Fair	Good.
Pacific Sugar Corporation	2	...do	$Na-CO_3$	...do	Fair.
City of Corcoran	7	...do	...do	Good	Do.
D. W. Lewis	2	...do	...do	Fair	Do.
L. P. Denny	1.1	Very high	...do	Very bad	Bad.
Jess & Gates	3.6	...do	$Na-SO_4$	...do	Poor.
Do	1	Moderate	$Na-CO_3$	Fair	Fair.

f Color, 40 parts.
g Color, 140 parts.

Owner.	Dat	Classification. ...emical ...aracter.	Quality for boilers.	Quality for irrigation.	Analyst.
W. D. Sprague	Nov.	$-CO_3$	Fair	Fair	F. M. Eaton.
Rhodes estate	...do	lo	Bad	Poor	Do.
Southern Pacific Co	June 2	-Cl	Fair	Fair	Southern Pacific Co.
Santa Fe Ry. Co	Oct.	lo	...do	...do	Kennicott Water Softener Co.
Pacific Coast Oil Co	....	lo	Good	Good	Pacific Coast Oil Co.
Santa Fe Ry. Co	Oct.	$-CO_3$	Very bad	Poor	Kennicott Water Softener Co.
L. P. Denny	Nov. 2	lo	...do	Bad	F. M. Eaton.
Jess & Gates	...do	lo	Fair	Fair	Do.

l; depth unknown.

TABLE 56.—*Field assays of ground waters in Kings County.*

[Parts per million except as otherwise designated.]

Owner.	Date, 1910.	Location. Sec.	T.	R.	Depth of well (feet).	Determined quantities. Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Computed quantities. Total solids.	Scale-forming ingredients (s).	Foaming ingredients (f).	Probability of corrosion [a] (c).	Alkali coefficient (k) (inches).	Classification. Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.
J. E. Meadows	Nov. 11	14	21 S.	18 E.	170	0	71	295	70	460	640	500	10	C.	30	High	Ca-SO_4	Bad	Good.
Do	...do	24	21 S.	18 E.	285	Tr.	53	312	50	80	620	110	500	?	20	...do	Na-SO_4	Very bad	Do.
	Nov. 12	11	19 S.	19 E.	100	6	27	2,760	370	880	4,800	910	3,400	C.	3	Very high	...do	...do	Poor.
E. P. McAdams	Nov. 10	25	19 S.	19 E.	38	0	145	44	35	155	300	200	80	?	55	Moderate	Ca-CO_3	Fair	Good.
F. Blakeley	Nov. 11	5	22 S.	19 E.	225	Tr.	78	276	35	81	560	110	430	?	27	High	Na-SO_4	Bad	Do.
W. D. Sprague	Nov. 9	22	18 S.	20 E.	106	12	176	Tr.	5	24	230	70	200	N. C.	9	Moderate	Na-CO_3	Fair	Fair.
Rhodes estate	...do	28	18 S.	20 E.	700	15	268	Tr.	20	11	340	60	360	N. C.	5	...do	...do	Bad	Poor.
R. W. Dougherty	Nov. 10	15	19 S.	20 E.	139	9	437	Tr.	20	43	450	70	490	N. C.	4	...do	...do	Very bad	Do.
M. A. Heinlen	...do	21	19 S.	20 E.	11	0	142	208	60	127	[b] 560	160	400	N. C.	22	High	Na-SO_4	Bad	Good.
Do	...do	21	19 S.	20 E.	400	15	542	Tr.	20	15	[c] 550	40	650	N. C.	2.8	...do	Na-CO_3	Very bad	Poor.
C. C. Friend	...do	29	19 S.	20 E.	375	9	354	121	45	36	[d] 600	70	620	N. C.	4	...do	...do	...do	Do.
	Nov. 12	33	19 S.	20 E.	30	0	278	2,155	305	1,560	[b] 3,900	1,600	1,800	C.	4.5	Very high	Na-SO_4	...do	Do.
W. N. Stratton	...do	17	20 S.	20 E.	850	0	636	10	70	122	[e] 700	150	700	N. C.	2.9	High	Na-CO_3	...do	Do.
J. F. Poole	...do	20	20 S.	20 E.	386	Tr.	398	381	25	96	[e] 980	130	900	N. C.	4.2	...do	Na-SO_4	...do	Do.
C. E. Mort	...do	29	20 S.	20 E.	369	Tr.	450	240	25	89	[e] 810	120	770	N. C.	3.8	...do	Na-CO_3	...do	Do.
Mrs. M. Dutra	Nov. 9	22	18 S.	21 E.	50	0	58	Tr.	5	46	110	70	10	N. C.	400	Low	Ca-CO_3	Good	Good.
William Hogle	...do	23	18 S.	21 E.	100	0	192	Tr.	5	57	220	110	150	N. C.	12	Moderate	Na-CO_3	Fair	Fair.
D. Ross	Nov. 13	1	19 S.	21 E.	40	3	244	65	65	147	450	200	300	N. C.	11	...do	...do	Bad	Do.
Ernest Howe	...do	25	19 S.	21 E.	85	0	149	5	15	48	210	100	130	N. C.	15	...do	...do	Fair	Do.
A. P. Reiding	...do	36	19 S.	21 E.	783	12	104	5	30	22	220	70	180	N. C.	12	...do	...do	...do	Do.
W. S. Burr	...do	2	20 S.	21 E.	44	3	344	10	30	140	420	170	270	N. C.	8	...do	...do	Bad	Do.
Mrs. E. M. Killmer	...do	25	20 S.	21 E.	95	Tr.	439	127	225	186	960	220	840	N. C.	3.6	High	...do	Very bad	Poor.
Dallas school district	...do	36	20 S.	21 E.	400	Tr.	728	Tr.	75	70	780	100	850	N. C.	2.3	...do	...do	...do	Do.
J. Martella	...do	1	21 S.	21 E.	1,100	Tr.	192	Tr.	25	22	260	70	230	N. C.	9	Moderate	...do	Fair	Fair.
Do	...do	1	21 S.	21 E.	1,600	0	115	Tr.	85	28	300	80	270	N. C.	9	...do	Na-Cl	...do	Do.
	Nov. 23	17	24 S.	21 E.	20	0	524	1,130	740	920	3,400	950	2,300	?	2.4	Very high	Na-SO_4	Very bad	Poor.
W. H. Thayer	...do	13	21 S.	22 E.	40	0	153	Tr.	15	95	210	140	70	N. C.	35	Moderate	Ca-CO_3	Fair	Good.
Pacific Sugar Corporation	...do	14	21 S.	22 E.	1,865	9	99	Tr.	35	17	210	70	180	N. C.	12	...do	Na-CO_3	...do	Fair.
City of Corcoran	Nov. 22	14	21 S.	22 E.	1,000	9	99	Tr.	15	29	180	80	120	N. C.	17	...do	...do	Good	Do.
D. W. Lewis	Nov. 23	21	21 S.	22 E.	1,200	6	164	Tr.	15	43	[f] 220	90	160	N. C.	12	...do	...do	Fair	Do.
L. P. Denny	...do	15	22 S.	22 E.	216	0	1,680	Tr.	490	535	[g] 2,300	560	2,100	N. C.	1.1	Very high	...do	Very bad	Bad.
Jess & Gates	...do	23	22 S.	22 E.	102	0	735	1,640	460	1,760	[b] 3,800	1,800	1,600	?	3.6	...do	Na-SO_4	...do	Poor.
Do	...do	23	22 S.	22 E.	1,424	Tr.	162	Tr.	35	44	[f] 250	90	190	N. C.	11	Moderate	Na-CO_3	Fair	Fair.

[a] C., corrosive; N. C., noncorrosive; ?, corrosion uncertain or doubtful.
[b] Color, zero.
[c] Color, 66 parts.
[d] Color, 154 parts.
[e] Color, moderate.
[f] Color, 40 parts.
[g] Color, 140 parts.

TABLE 57.—*Mineral analyses of ground waters in Kings County.*

[Parts per million except as otherwise designated.]

Owner.	Date.	Location. Sec.	T.	R.	Depth of well (feet).	Determined quantities. Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Computed quantities. Scale-forming ingredients (s).	Foaming ingredients (f).	Probability of corrosion (c).	Alkali coefficient (k) (inches).	Classification. Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.	Analyst.
W. D. Sprague	Nov. 9, 1910	22	18 S.	20 E.	106	......	0.30	12	2.0	[a] 69	Tr.	210	6.6	6.0	266	90	190	N. C.	10	Moderate	Na-CO_3	Fair	Fair	F. M. Eaton.
Rhodes estate	...do	28	18 S.	20 E.	700	......	.40	7	2.2	[a] 124	14	295	0	22	386	75	340	N. C.	5.6	...do	...do	Bad	Poor	Do.
Southern Pacific Co.	June 25, 1891	33	18 S.	21 E.	540	[b] 30	......	3	Tr.	94	0	114	14	75	272	40	250	N. C.	10	...do	Na-Cl	Fair	Fair	Southern Pacific Co.
Santa Fe Ry. Co.	Oct. 1, 1902	35	18 S.	21 E.	......	[b] 118	......	4	Tr.	84	0	104	8	70	335	130	230	N. C.	11	...do	...do	...do	...do	Kennicott Water Softener Co.
Pacific Coast Oil Co.	......	14	21 S.	22 E.	850	[b] 27	......	6	2	25	0	26	24	21	152	50	70	N. C.	85	Low	...do	Good	Good	Pacific Coast Oil Co.
Santa Fe Ry. Co.	Oct. 1, 1902	14	21 S.	22 E.	([c])	39	......	22	1	264	0	727	4	21	710	105	710	N. C.	2.6	High	Na-CO_3	Very bad	Poor	Kennicott Water Softener Co.
L. P. Denny	Nov. 23, 1910	15	22 S.	22 E.	216	......	1.40	80	111	[a] 750	0	1,952	0	492	2,452	450	2,000	N. C.	1.1	Very high	...do	...do	Bad	F. M. Eaton.
Jess & Gates	...do	23	22 S.	22 E.	1,424	......	1.00	18	3.4	[a] 66	0	187	0	35	220	110	180	N. C.	12	Moderate	...do	Fair	Fair	Do.

[a] Computed.
[b] Including oxides of iron and aluminum.
[c] Artesian well; depth unknown.

QUALITY OF WATER.

The quality of the water around Tulare Lake has been discussed in detail in pages 104–109. Along the northern and eastern borders of the county dependence is placed almost exclusively in artesian wells 1,000 to 2,000 feet deep for irrigation supplies. These wells yield fair water. Close to the lake and within its borders wells 20 to 300 or 400 feet deep yield very poor water, but the quality of water between those depths grows better in proportion to distance from the center of the lake.

Means's tests reported by Lippincott[1] indicate that the waters near the surface immediately east and southeast of Hanford are poor in quality; the areas around the 40-foot well in sec. 1, T. 19 S., R. 21 E., and the 42-foot well in sec. 2, T. 18 S., R. 23 E., may form part of the same territory.

Wells 1,200 to 1,800 feet deep along the eastern border of the county yield water excellent for all uses.

Three sulphate waters west of the lake are acceptable in irrigation; that from the 285-foot well in sec. 24, T. 21 S., R. 18 E., is being applied to vines, garden truck, and small fruit trees. The quality of water likely to be struck by wells south and southwest of the lake is problematical for that region includes the marshy overflow lands across which the discharge of Kern River has passed, and as the silts there have probably been derived from both east-side and west-side encroachments it can not be assumed that the waters from them would be of the west-side type. It seems probable, however, that supplies similar to those in T. 22 S., R. 22 E., would be found in T. 23 S., R. 22 E., and that artesian waters in T. 22 S., R. 19 E., and T. 23 S., R. 20 E., would be similar to that from the 225-foot well in T. 22 S., R. 19 E.

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[1] Lippincott, J. B., Storage of water on Kings River, California: U. S. Geol. Survey Water-Supply Paper 58, pp. 56–79, 1902.

WELL RECORDS.

The details of depth, cost, equipment, and use of such wells as the Survey has examined have been assembled in the accompanying table.

TABLE 58.—*Records of wells in Kings County.*

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.[a]	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
	3	17	22	1895	Bored, 5 inches	107	12		Hand	D			$4.00
Sacramento Bank	4	17	22	1888	do	50	15		do	D, S		$37	5.00
E. Rae	1	17	22	1889	do	34	9	66	do	D		17	
S. Sweet	25	17	22	1884	do	35	8		do	D			3.50
E. Jacobs	25	17	22	1885	Bored, 8 inches	60	9		Wind	D, S		45	6.00
David Burris	27	17	22	1886	Bored, 5 inches	40	12		Wind, hand	D			
Do	22	17	22	1900	do	33	9		Hand	D, S		33	5.00
Mr. Van Dorset	29	17	22	1900	do	44	8		do	D		60	4.00
T. J. Alcorn	25	17	21	1900	do	42	11		do	D, S			
C. W. Clark	36	17	21	1885	do	60	11		do	D, S		14	5.00
C. J. McCullah	35	17	21	1890	do	52	7		do	S		36	3.50
Boston Raisin Co.	3	18	21	1896	do	52	10		do	D, S		26	3.50
A. J. Cortner	1	18	21	1891	do	38	12		do	D		28	3.00
Mr. Jenkins	4	18	22		do	30	8		do	D, S			3.00
Cosmos Land & Water Co.	33	17	22	1874	Bored, 6 inches	65	8		do	D		65	6.00
Montgomery Bros	34	17	22	1900	Bored, 5 inches	56	13		do	D		28	3.50
David Burris	12	18	22	1900	do	58	8		do	D, S		37	6.00
S. A. Thompson	10	18	22	1889	do	66	8			D			
J. R. High	20	18	22	1897	do	25	6		Hand	D		13	
E. Jacobs	17	18	22		do		11		do	D, S			3.00
L. N. Gregory	13	18	21	1888	do	82	7		do	D		41	4.00
M. Bassett	14	18	21	1898	do	44	10		do	D, S		22	4.00
S. S. Serderberg	11	18	22	1886	do	54	8		do	D, S		39	3.50
Mrs. M. A. Haws	9	18	21	1891	do	50	8			D			
J. W. Lane	22	18	21		do	61	9		Wind	D		31	30.00
C. Lathan	18	18	21	1890	do	40	6		do	D, S		20	65.00
Mr. Page	24	18	20	1900	do	24	8		Hand	D, S			4.00
Mike Dutra	22	18	21	1889	do	50	9		do	D			4.00
Wm. Hogle	23	18	21	1897	Bored, 2 inches	100	8		do	D, S		50	4.50
J. O. Hickman	25	18	21	1890	Bored, 5 inches	24	7		do	D, S		18	4.00
J. C. Rice	18	18	22	1888	do	54	6		Wind	D, S		48	38.00

Wetmore Bros.	29	18	22	1885	Bored, 7 inches	35	8		Wind, hand	D, S		27	
H. Marshall	17	18	22	1900	Bored, 5 inches	92	7		Hand	D, S			
R. W. Morgan	15	18	22	1888	do	60	9		do	D, S			5.00
E. Y. Bock	24	18	22	1878	Bored, 4 inches	70	12		do	D, S			
J. McCabe	21	18	23	1891	Bored, 5 inches	37	11	70	Wind	D, S		20	200.00
Alexander Taylor	22	18	22	1894	do	40	7		Hand	D, S		20	4.00
F. G. Ferreiro	22	18	22		do	35	6		do	D			4.00
Perry C. Phillips	25	18	22	1900	do	138	12		do	D			
Do	36	18	22		do		16		do	D			4.00
Joe Rogers	28	18	22		do		11		do	D			3.00
C. Waldorf	5	19	22		Bored, 4 inches		8		do	D, S			6.00
Frank Griffith	29	18	22	1894	Bored, 5 inches	38	12		do	D		27	
Mr. Dunner	31	18	22	1888	do	28	10		do	D, S		14	3.00
J. E. Rawlins	1	19	21	1882	Bored, 6 inches	42	10.5		Wind	D, S		42	150.00
A. L. Cressy	35	18	21	1884	Bored	25	10		do	D, S		25	50.00
P. C. Eccles	35	18	21	1891	Bored, 4 inches	40	10		do	D, S			
W. V. Walker	34	18	21	1890	Bored, 5 inches	35	10		Hand	D, S			3.00
Maria Reynolds	33	18	21	1885	do	36	12		do	D			6.00
Ben Scribner	4	19	21		do	70	10		do	D			4.00
W. W. Robinson	31	18	21	1888	Bored, 6 inches	42	10		do	D		21	3.50
Mrs. M. Camp	30	18	21	1880	Bored, 5 inches	32	10		Wind	D		32	53.00
W. J. Weir	36	18	20	1890	do	40	10		Hand	D			
Mrs. H. Bryant	36	18	20	1880	do	50	12		do	D		50	4.00
Mrs. Hunkey	34	18	20		do		8		do	D, S			4.00
R. M. Coon	4	19	20	1887	Bored, 8 inches	52	8		Wind	D			
Lemoore Electric Light & Waterworks Co.[b]	3	19	20	1902	Bored, 7 inches	180	0		Steam, artesian	D	11	300	
O. D. Brown	1	19	20	1883	Bored, 5 inches	40	4		Hand	D, S			3.00
C. Manter	8	19	21	1879		50	8		do	D, S			3.00
Chas. Feahill	9	19	21	1890	Bored, 5 inches	48	8		do	D		23	3.50
F. E. Wood	3	19	21	1890	do	50	8		do	D, S			
Mrs. M. Andrews	20	19	21	1882	do	60	10		do	D			4.00
John Wynrck	2	19	21	1884	Bored, 7 inches	608	0		Artesian	D, S	2	1,333	
Philips estate	7	19	22	1895	Bored, 5 inches	40	10		Hand	D, S			6.00
M. Braverman	9	19	22		do		9		do	D, S			
Harry Peacock	3	19	22	1873	do	75	9		Wind, hand	D			
R. Abbott	3	19	22	1889	Bored, 4 inches	100	9		Hand	D, S		50	3.00
J. H. Murray	12	19	22	1892	Bored, 5 inches	43	14		do	D, S		40	3.25
P. Sweeney	14	19	22	1878	do	40	8		do	D, S		40	2.25
G. L. Fletcher	15	19	22	1889	do	56	10		do	D, S		56	
Mrs. M. J. Covert	22	19	22	1878	do	40	14		Hand, wind	D, S			
Susan Hill	20	19	22	1899	do	30	10		Wind	S			35.00
F. L. Sanborn	18	19	23	1903	do	46	12	66	do	S		25	
W. A. Sanborn	17	19	23	1875	Bored, 6 inches	40	14	69	Hand	D, S		20	4.00
F. L. Sanborn	25	19	22	1892	Bored, 7 inches	+32	12	66	Wind	S			
Robert Dougherty	23	19	22		Bored, 5 inches	30	14		Hand	D, S			
S. L. Worley	28	19	22	1880	do	30	13		do	D, S			3.50
S. A. Brewer	20	19	22	1891	do	54	12		do	D, S		30	2.50
California Savings & Loan Association	25	19	21	1880	Bored, 6 inches	55	9		do	D		55	7
C. H. Watson	19	19	22	1893	Bored, 5 inches	45	8		do	D, S			
R. S. Wait	13	19	21	1878	Bored, 6 inches	40	10		do	D			

[a] D, domestic; S, stock; I, Irrigation; B, boilers; N, not used.

[b] Two wells.

TABLE 58.—*Records of wells in Kings County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	*°F.*			*Miner's inches.*		
Fred Ward	26	19	21		Bored, 5 inches		9		Steam	D			$130.00
John Sigler	26	19	21	1892	do	65	12		Wind	D, S			
J. R. Mullinix	14	19	21	1880	Bored, 6 inches	40	12		Hand	D		$41	4.00
Martin Roberts	22	19	21	1882	Bored, 5 inches	25	12		do	D			3.00
J. L. Walker	8	19	21	1897	do	66	9		do	D, S		33	4.00
L. R. Love	20	19	21	1890	do		12			D, S			
Geo. W. Houston	21	19	21	1890	do	34	12		Hand	D, S			4.00
B. R. Nidiffer	19	19	21	1875	do	37	10		do	D, S			3.00
G. E. Shore	18	19	21	1889	Bored, 7 inches	40	10		Wind, hand	D, S			
J. F. Florey	13	19	20	1885	Bored, 5 inches	40	8		do	D			
W. D. Runyon	12	19	20	1896	do	122	7		Hand	D, S		61	3.50
E. W. Clithero	14	19	20	1890	do	60	6		do	D, S			6.00
Mrs. E. Cory	14	19	20	1882	Bored, 6 inches	33	8		do	D		17	3.25
R. W. Dougherty	15	19	20	1892	Bored, 5 inches	139	3.5		do	D, S		108	4.00
John Hunlen	16	19	20		Bored, 7 inches	+100	0		Artesian	D	Small.		
M. A. Heinlen	8	19	21	1897	Bored, 4 inches	135	0		do	D, S		135	
Do	20	19	20	1901	Bored, 2 inches	265	0	76	do	S	Small.		
Bates & Miller	19	19	20	1902	do	335	0	77	do	S	Small.		
M. A. Heinlen	21	19	20	1880	Bored, 7 inches	400	0	77	do	S	Small.		
M. Hinniel	21	19	20		Bored, 6 inches	36	6		Hand	D		20	
M. A. Heinlen	28	19	20	1902	Bored, 5 inches	34	7		do	D, S		17	
C. C. Frand	29	19	20	1905	Dug, 2 feet	16	5		do	D			
Do	29	19	20		Bored, 6 inches	590	2		do	S			
E. P. McAdams	25	19	19	1897	Bored, 4 inches	38	6	66	do	D, S		20	
Bates & Miller	6	20	20	1903	Bored, 2 inches	350	0		Artesian	S	Small.		
M. A. Heinlen	5	20	20	1895	do	398	0	77	do	S	Small.	400	
Harris & Hereford	33	19	20	1904	Bored, 5 inches	34	7	66	Hand	D, S			
Jacobs estate	27	19	20		Bored, 9 inches		0	77	Artesian	S	3		
L. Hereford	22	19	20	1885	Bored, 12 inches	36	6		Hand	D			
J. Childres	26	19	20		Bored, 6 inches	30	5		do	D		15	
S. T. Whiteside	26	19	20		Bored, 5 inches	46	6	66	do			26	
W. Blevins	26	19	20	1892	Bored, 6 inches	40	10		do	D, S		20	3.00
E. Jacobs	2	20	20		Bored, 9 inches		0		Artesian	D, S	Small.		
E. G. Sellers	36	19	20	1895	Bored, 5 inches	52	12		Hand	D			3.50
Marriott & Mathus	30	19	21	1898	do	104	12		do	D, S		54	3.50
M. F. Mines	4	20	21	1891	do	83	14		do	D, S			3.00
C. Paddock	4	20	21		do	35	13		do	D, S			3.50
W. Burr	10	20	21		Bored, 7 inches		13		do	D			4.00

W. S. Burr	2	20	21	1900	Bored, 5 inches	44	16		Wind	D, S		22	31
John Bowers	36	19	21	1894	Bored, 9 inches	800	0		Artesian	D, S		1,600	
A. P. Redding	36	19	21	1889	Bored, 10 inches	783	0		do	I, D	38	2,600	
Mrs. J. Hide	12	20	21		Bored		15		Hand	D, S			5.00
Geo. Clute	31	19	22	1885	Bored, 10 inches	900	0		Artesian	I, D, S		1,900	
A. & J. Toomey	32	19	22		Bored, 6 inches		0		do	S			
Lakeside Creamery Co	33	19	22	1890	Bored, 5 inches	60	15		Hand	D		45	12.00
Mrs. J. T. Hereford	34	19	22	1875	Bored, 6 inches	40	11		do	D		40	6.00
E. McCarthy	3	20	22		Bored, 5 inches	64	14		do	D, S		64	2.75
J. McCann	2	20	22	1904	do	32	10	67	do	D		16	
Mr. Hunter	13	20	22	1890	Bored, 9 inches	+900	0	77	Artesian	I, S	36		
W. H. Heldebrand	10	20	22	1880	Bored, 5 inches	34	16		Wind	D, S		34	114.0
P. McCarthy	8	20	22	1886	Bored, 9 inches	600	0		Artesian	I, D, S		1,500	
F. E. Howe	8	20	22	1891	Bored, 8 inches	750	0		do	I, D, S		1,250	
J. McCann	15	20	22	1905	Bored, 5 inches	38	8	66	Hand	D			
Do	21	20	22		do	35	8		do	D			
Mrs. E. M. Killmer	25	20	21		Hydraulic, 2 inches	95	12	67	Wind	D, S		50	
Henry C. Smith	26	20	21	1904	Bored, 2 inches	400	0		Artesian	S	2	400	
J. Boyle	36	20	21		Bored, 8 inches	700	0	73	do	D, S	33		
Dallas school district	36	20	21	1905	Bored, 2 inches	400	0	73	do	D	1		
Mr. Martelas	1	21	21		Bored, 11 inches	1,100	0	76	do	D, S	34		
Jacobs estate	7	20	21		Bored, 9 inches		0	77	do	S	9		
Do	13	20	20		do		0		do	S	26		
Do	11	20	20	1883	do		0	77	do	S	9		
Do	2	20	20		do		0	77	do	S	9		
Pacific Coast Oil Co	10	20	20	1904	Bored, 10 inches	820	0	77	do	B	30		
Bates & Miller	16	20	20	1890	Bored, 7 inches	775	0		do	D, S	7		
Jacobs estate	23	20	20		Bored, 9 inches		0	77	do	S	3		
Do	27	20	20		do		0		do	S	46		
Bates & Miller	33	20	20		Bored, 2 inches	360	0		do	N			
Do	32	20	20	1903	do	325	0	76	do	S	Small.		
Do	30	20	20	1903	do	350	0	76	do	S	Small.		
Do	31	20	20	1900	do	260	0	76	do	S	Small.	260	
Edgar & Combs	1	21	19	1905	do		0	76	do	S	Small.		
F. Blakeley	11	21	19	1895	do	217	0	76	do	S	Small.		
N. L. Palmer	22	21	18	1892	Bored, 8 inches	210	40		Wind	N			
F. Blakely	5	22	19	1890	Bored, 2 inches	225	0	76	Artesian	S	Small.		
Do	3	22	19		do	236	0		do	S	Small.		
L. D. Combs	12	21	19		do	250?	0	76	do	S	Small.		
G. A. Smith	8	21	20		do	225	0	76	do	S	Small.		
M. Lovelace	5	21	20	1903	do	250	0		do	S	Small.		
Do	5	21	20	1901	do	300	0	76	do	D, S	Small.		
Do	4	21	20	1903	do	250	0	74	do	S	Small.		
Do	4	21	20	1904	do	240	0	75	do	S	Small.		
R. Mills	15	21	20	1904	do	350			Not raised	N			
Sam Richardson	16	21	21		do	200	0		Artesian	S			
Do	22	21	21		Bored, 3 inches	90	0	66	do	S, D	Small.		
J. Martella	1	21	21	1905	Bored, 10 inches	1,600	0	78	do	I, S	36		
Mrs. McDonald	12	21	21	1905	Bored, 8 inches	1,250	0		do	I, D, S			
R. G. Hunter	6	21	22	1901	Bored, 6 inches	450	0	74	do	S		500	
	19	21	22		Hydraulic, 2 inches		0	72	do	S	Small.		
	20	21	22		do		0	70	do	D, S	Small.		

TABLE 58.—*Records of wells in Kings County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
F. Ganahl	30	21	22		Hydraulic, 2 inches	350	0	70	Artesian	D, S	3		
D. W. Lewis	21	21	22	1905	Bored, 6 inches	1,225	0	74	do	I	22		
Do	21	21	22	1905	do	1,200	0	74	do	I	33		
Do	21	21	22	1905	do	1,247	0	72	do	I	43	$1,550	
Do	21	21	22	1905	do	1,106	0	72	do	I			
Security Land & Loan Co	14	21	22		Bored, 8 inches		0	74	do	I	8		
Do	14	21	22		do		0	74	do	I, D, S	8		
Do	14	21	22	1905	Bored, 12 inches	928	0	71	do	I	30	3,000	
Do	24	21	22	1891?	Bored, 7 inches		0	71	do	I	20		
A. Y. Thayer	13	21	22	1905	Bored, 13 inches	60	10.5?		Gas	I	*a* 33	50	$800.00
W. H. Thayer	13	21	22		Bored, 5 inches	40	10		Hand	N		20	4.00
Dr. Dixon	4	22	22		Bored, 2 inches	150?	0	66	Artesian	S	Small.		
N. Hausen	10	22	22	1905	Hydraulic, 2 inches	360	0	68	do	D, S		180	
Mrs. Duncan	10	22	22	1904	Bored, 6 inches	350	0	71	do	D, S			
L. P. Denney	15	22	22	1901	Bored, 8 inches	950	0	72	do	I, D, S	24	2,400	
Do	14	22	22	1904	Hydraulic, 2 inches	250	0	72	do	S	Small.	300	
C. Lamberson	12	22	22		Bored, 8 inches		0	76	do	D	*a* 25		
	13	22	22		do		0	75	do	I, S	17		
	13	22	22		Hydraulic, 4 inches		0	68	do	I, S	2		
	13	22	22		Bored, 6 inches		0	78	do	I. S	44		
O. P. Quimby	24	22	22		Bored, 12 inches	1,200	0	78	do	I, D, S	13	3,000	
Robert Boot	25	22	22	1905	Bored, 6 inches	1,540	0	85	do	I, D, S	61	4,000	
Do	25	22	22	1904	Bored, 2 inches	308	0	71	do	S	Small.		
	20	22	22		Bored, 12 to 10 inches.		0	70	do	N	Small.		
R. D. Hunter	30	22	22	1905	Hydraulic, 2 inches	120	20?	70	Hand	S		70	5.00
Southern California Savings Bank	4	23	22		do	400	0		Ceased flowing	S			
J. N. Sherwin	7	23	21	1904	do	200	2		Horse	S		200	100.00
F. Blakeley	17	22	20		Bored, 2 inches	262	0		Artesian	S	Small.		
Do	19	22	20		do	200+	0		do	S	Small.		
Miller & Lux	28	24	22		Bored, 8 inches		0	77	do	I, D, S	23		
Pacific Coast Oil Co	14	21	22		Bored, $9\frac{5}{8}$ to 8 inches	850	0		do	B	13		
Do	10	20	20	1904	Bored, 10 to 8 inches.	1,000	0		do	B	3		

a Yield estimated or statement of owner taken.

KERN COUNTY.

GENERAL CONDITIONS.

Kern County, which includes the extreme southern end of the San Joaquin Valley, receives its principal water supply, both surface and underground, from Kern River, which flows out upon the valley floor just above Bakersfield. Minor amounts, chiefly as winter flood waters, are contributed by Poso Creek and the streams that enter the valley from the south and west. The supply in excess of that used by the canal systems flows into Buena Vista Reservoir, where it is stored for the irrigation of the Miller & Lux lands along the trough of the valley to the north. During seasons of particularly heavy stream flow, a portion of the water escapes northward along either the main channel or Goose Slough channel toward Tulare Lake. This county has the least precipitation of all those in San Joaquin Valley, the average for a long period at Bakersfield being 4.81 inches,[1] and consequently the direct supply of surface water is markedly small.

In the course of its distribution over the delta lands through the canals in irrigation, and by flow through the natural distributaries, a definite portion of the water sinks and so maintains a condition of saturation of the sands and gravels that have been deposited in the course of the growth of the delta. These saturating waters, like the surface waters, move in the direction of the slope of the delta, but at a much slower rate. They circulate more freely through the coarser beds of the delta deposits, and as they pass beneath the finer beds that are more numerous in those parts of an alluvial fan that are most distant from its head they accumulate pressure. Therefore when the confining beds above them are pierced by a well they rise, and if the pressure is sufficient they flow over the surface. These are the flowing artesian wells of the beds of Kern and Buena Vista lakes and the region extending some miles north of them, and of the main San Joaquin Valley artesian basin, beginning in the neighborhood of Buttonwillow and extending thence northward down San Joaquin Valley to the delta of San Joaquin and Sacramento rivers. It may connect with the Buena Vista artesian area, although there is no evidence available now to determine this point.

FLOWING WELLS.

In 1905 there were 112 flowing wells in the county that were examined, and there were doubtless a few more that were not seen. The yield of these was in the neighborhood of 70 or 75 second-feet. About one-third of the wells were used for irrigation, the remainder being

[1] Cone, V. M., Irrigation in the San Joaquin Valley, California: U. S. Dept. Agr. Off. Exper. Sta. Bull. 239, p. 11, 1911.

used for stock or domestic purposes or allowed to waste. The areas in which they occur are indicated by the outlines of the artesian basins, as shown on Pl. I (in pocket).

Generally speaking, the artesian pressures have not been seriously affected by the developments that have taken place to date, although there are some wells, as in the Semitropic district, whose flow has decreased markedly as a result of the boring of big wells near by, but on lower ground and therefore in more favorable situations. Artesian wells usually deteriorate with age, as a result of any one of several causes, as slow filling with sand, clogging by gelatinous growths of microscopic organisms, and deterioration of the casing.

The State Engineering Department of California measured the yield of certain flowing wells in the Kern delta in 1885, and some of these were remeasured in 1905. The remeasured wells show decreases in yield varying from 50 to 100 per cent, but in only one of the wells available for comparison has there been complete cessation of flow. Decrease in yield of individual wells as development progresses is so usual a phenomenon that no community can safely plan its future on the assumption that a cheap supply of this type will remain constant, even in such large basins as those of the San Joaquin. But flowing water should be available for years from those wells whose initial yield is sufficiently large to be of value. Later, when the communities are more thickly settled and the wells are so closely grouped that flow and yield are materially decreased, industrial conditions may have so changed that pumps can profitably be installed to augment the supply. The cost of such pumped waters will usually be particularly low, because of the slight lift required to bring them to the surface.

PUMPING PLANTS.

In 1906 there were more than 100 pumping plants in Kern County developing underground water for various purposes. Of these about 40 were gas plants, 25 were steam plants, and the rest were electric. Nearly all of the steam plants have been abandoned or replaced with plants using gas engines or electric motors. The developed waters are used for irrigation, for city supplies, for engine waters, and as supplies for steam plants, as at the pumping stations of the Pacific Coast Oil Co.

In the district about Bakersfield 50 pumping plants are in use to develop irrigation water. Half of these are electrically operated and belong to the Kern County Land Co. Each of these plants is equipped with 30 or 40 horsepower motors directly connected with No. 8, 10, or 12 centrifugal pumps. Each pump is connected with from one to four 13-inch wells, the number being determined by the yield of each well. From the data collected on these wells the fol-

lowing cost averages were computed on the basis of the quoted charge of 15 cents per horsepower per 24 hours for the electric power used.

TABLE 59.—*Data concerning pumping plants in Kern County.*

Average depth to the water from the surface, in feet	10
Average suction 20 feet. Average total lift, in feet	30
Total yield of 25 plants, in second-feet	100.34
Total horsepower consumed	860
Total cost per day for current to develop 100.34 second feet, 860 H. P., at 15 cents	$129.00
Cost per second-foot for 24 hours	$1.29
Cost per acre-foot of water developed	$0.65

The company estimates that other items bring the total cost of operation and maintenance to $1.70 per second-foot for 24 hours or 85 cents per acre-foot. Taxes, interest, and depreciation amount to about 15 per cent on the investment, and as the plants are operated about 100 days a year these items increase the total cost of developing ground water to $3 per second-foot for 24 hours or $1.50 per acre-foot.

The standard of water costs in this district is set by the price of gravity water from the Kern—75 cents per second-foot for 24 hours, or about 38 cents per acre-foot, where distribution is affected by sales.

The pumped water therefore, even under the excellent system of the Kern County Land Co., costs about four times as much as the gravity water, and its cost will increase as it is developed from deeper strata with higher lifts. It seems to be quite generally believed locally that water at these prices can not be used profitably.

This may be true with the wasteful methods employed, the excessive amounts of water often applied, the class of crops produced, and the general lack of intensive cultivation; but it has been clearly proved in other communities and by individual experiences in the Bakersfield region itself that with more diversified or better selected crops, smaller individual holdings, and more intensive methods of farming, good profits may be made from the alkali-free lands of the delta and plains by the careful use of water at these or at even higher prices. It is safe to predict that the most important future developments in Kern County will result from the application of these principles.

Under any conditions that are likely to obtain in the near future it is not to be expected that ground waters at greater depths than 25 or 30 feet below the surface as an extreme will be usable for irrigation purposes. Water at this or less depths exists, of course, throughout the artesian areas along the lowest parts of the valley. It is to be found also throughout the greater part of Kern delta and in the lower parts of Poso Creek delta from a point about halfway between Famoso and Wasco westward. Near the foothills on each side of the

valley the ground water is not accessible except under unusual conditions, as in the flood plains of the larger rivers, or in areas where particularly valuable products, such as citrus fruits, will justify the expense of pumping to exceptional heights. In the intermediate areas between the deltas of the streams that supply the ground water it is also apt to be too deep to be accessible. This condition is illustrated in the area between Kern and Poso Creek deltas, east of Shafter station, on the Santa Fe Railway, and in the region between Delano and the foothills just south of the Tulare County line.

Near the northern edge of the county the main artesian belt of the valley, whose southern end is in the vicinity of Buttonwillow, expands to a width of 26 or 27 miles measured along the county line. Much of this central portion of the valley along the north edge of Kern County is in large holdings and is therefore but thinly settled, but developments are ample to prove the artesian conditions and to permit outlining the artesian belt with a fair degree of accuracy. The outlines as determined are shown on the map (Pl. I, in pocket), which also shows by means of hydrographic contours the depth to the ground-water level outside the artesian limits.

Although little direct evidence bearing upon this point exists, there can be no doubt that beneath the broad steeply sloping west-side plains of Kern County the ground water a few miles back from the trough of the valley is too deep to be accessible, because the water table has but little slope, the depth to it at any point being approximately equal to the elevation of that point above the trough of the valley.

QUALITY OF WATER.

The information regarding the quality of the ground waters of Kern County is more or less local, and therefore generalizations can not be made with such definiteness as in other parts of the valley. Water from wells of different depths around Delano, Famoso, and Oil Center was tested, and the basin of Kern Lake was explored. A line of assays was made from Famoso to Semitropic, and deep and shallow waters were examined as far west as Buttonwillow and T. 25 S., R. 23 E.

The chemical composition of waters in Kern County is somewhat different from that of supplies farther north, especially in respect to the distribution of sulphate. Five wells 43 to 220 feet deep at Delano yield waters good for irrigation and fair to poor for boiler use; all contain appreciable amounts of sulphate, but they are not nearly so strongly mineralized as the water of an 18-foot well, which carries 1,600 parts of total solids. Three wells east of Delano in T. 25 S., R. 26 E., 80 to 180 feet deep, yield sodium carbonate water low enough in mineral content to be good for irrigation. Water

from two wells 108 and 118 feet deep at Delano is being successfully used in irrigating orange trees.

Flowing wells 300 to 995 feet deep at Pond pumping station and west of there in T. 25 S., R. 24 E., yield sodium carbonate waters low in mineral content like those along the western border of Tulare County, and these waters have been used to irrigate alfalfa, grain, garden truck, and trees. The only shallow well that was tested gives a sodium sulphate water of poorer quality. The supply from a 700-foot well at Pond pumping station is used in boilers without treatment except preheating, and the assay shows that the water is low in all harmful constituents.

Wells 50 to 175 feet deep at Famoso yield calcium carbonate water, acceptable for irrigation and somewhat lower in mineral content than the average water of the east-side type farther north. Wells of similar depth west of Famoso yield inferior sodium carbonate water higher in sulphate. Wells 172 to 326 feet deep around Semitropic still farther west have supplies similar to those at Pond, and their waters have been similarly used. Water from the 480-foot well in sec. 8, T. 27 S., R. 23 E., curiously enough, is much higher in chlorine than that from the other wells. As the water of a 1,150-foot well in the same section has not been used for a long time and stands below the top of the casing the complete test of its water is not reported, but it shows the presence of 235 parts per million of chlorine. Water from the artesian well of S. B. Anderson, west of Semitropic, the depth of which is not reported, contains more than 700 parts of chlorine, according to an examination made in the State laboratories. All these wells probably lie in the eastern edge of a highly mineralized area, for deep waters east of this locality are low in chlorine.

The water that is pumped with the oil from wells in Kern River field contains little sulphate or chloride, but it is very hard. A battery of wells about 400 feet deep in sec. 5, T. 29 S., R. 28 E., and a 200-foot well in sec. 7, T. 29 S., R. 28 E., furnish boiler and drinking water moderate in mineral content and much better than that from deeper wells. No pretreatment is necessary for these supplies, and only a small amount of eggshell scale has to be removed from the boilers every two weeks.

Shallow waters as far south of Bakersfield as Kern Lake basin are fair for use in boilers and good for irrigation, as they are calcium carbonate waters of moderate mineral content. Their situation in a well-cultivated region supplied with surface water partly explains their excellent quality. The deeper waters in the lake basin farther south are of good quality, but they increase in sulphate southward, and those close to the foothills are bad. These changes are graphi-

cally represented in section D′ E′, figure 4, and they are more fully discussed on pages 109–110.

The poor quality of the ground waters in an alkali belt immediately southeast of Kern is proved by the tests of supplies in the eastern part of T. 30 S., R. 28 E. Three waters from wells 60, 140, and 240 feet deep south of this area are better.

Four flowing wells northeast of Buttonwillow, 444 to 850 feet deep, yield similar supplies. As they are sodium carbonate waters of low mineral content, similar to those at Semitropic and Pond, it is reasonable to conclude that flowing wells east of range 23 between Buttonwillow and Kings River will yield water good or fair for irrigation and for boiler use. A shallow well in sec. 31, T. 28 S., R. 24 E., gives water of the same nature. The low, broad, but well-defined ridge that lies between the artesian area in T. 28 S., R. 24 E., and that in T. 29 S., R. 23 E., may separate the two flowing-well basins. The fact that the three artesian supplies in the latter township are sodium chloride waters of poorer quality than those northward is significant but not conclusive, as conditions here may be analogous to those at Semitropic, where no such ridge exists. Two shallow wells at Buttonwillow yield hard water good for irrigation but poorer than that in T. 28 S., R. 24 E., while the 101-foot well at Buttonwillow depot yields still harder water.

Little information is available regarding the quality of the waters west of range 23, but the data given by Arnold and Johnson[1] regarding the springs and wells in the west-side hills establish their highly mineralized character. These supplies are probably similar in composition and concentration to the gypseous waters of western Fresno County.

[1] Arnold, Ralph, and Johnson, H. R., Preliminary report on McKittrick-Sunset oil region, Cal.: U. S. Geol. Survey Bull. 406, pp. 102–107, 1910.

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Owner.	l ..	Classification.			Analyst.
		Chemical character.	Quality for boilers.	Quality for irrigation.	
J. P. Irish	e..	Na-Cl	Bad	Fair	F. M. Eaton.
Southern Pacific Co	...	do	do	do	Southern Pacific Co.
Do	e..	$Ca-CO_3$	Fair	Good	Do.
Do	...	$Ca-SO_4$	do	do	Do.
Do	...	do	do	do	F. M. Eaton.
Do	...	$Ca-CO_3$	do	do	Southern Pacific Co.
Williams & Noyer	...	do	do	do	F. M. Eaton.
Southern Pacific Co	...	do	do	do	Southern Pacific Co.
Do	...	do	Good	do	Do.
Do	e..	$Ca-SO_4$	Poor	do	Do.
P. M. Wilkerson	...	$Ca-CO_3$	Fair	do	F. M. Eaton.
Kern County Land Co	...	$Na-CO_3$	Good	do	Do.
Southern Pacific Co	...	$Ca-CO_3$	Fair	do	Southern Pacific Co.
Petroleum Development Co.	gh.	Na-Cl	Very bad	Bad	F. M. Eaton.
Pacific Coast Oil Co	...	$Ca-CO_3$	Good	Good	Pacific Coast Oil Co.
E. A. Marriott	e..	do	Poor	do	F. M. Eaton.

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TABLE 60.—*Field assays of ground waters in Kern County.*

[Parts per million except as otherwise designated.]

Owner.	Date, 1910.	Location. Sec.	T.	R.	Depth of well (feet).	Determined quantities. Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Computed quantities. Total solids.	Scale-forming ingredients (s).	Forming ingredients (f).	Probability of corrosion[a] (c).	Alkali coefficient (k) (inches).	Classification. Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.
Mrs. C. Davis	Nov. 28	4	27 S.	23 E.	234	15	45	5	10	7	140	60	90	N. C.	25	Low	Na-CO_3	Good	Good.
Semitropic school district	..do	4	27 S.	23 E.	326	18	50	5	15	13	160	60	110	N. C.	20	Moderate	..do	..do	Do.
J. P. Irish	..do	8	27 S.	23 E.	480	12	70	Tr.	110	28	310	80	280	N. C.	10	..do	Na-Cl	Bad	Fair.
F. J. Randolph	..do	14	27 S.	23 E.	172	12	44	5	10	11	130	60	90	N. C.	20	Low	Na-CO_3	Good	Good.
P. Silas	Dec. 4	25	28 S.	23 E.	444	12	30	5	20	27	140	80	70	N. C.	40	..do	..do	..do	Do.
C. B. Crawford	..do	25	28 S.	23 E.	450	12	32	5	25	24	150	70	80	N. C.	35	..do	..do	..do	Do.
Miller & Lux	..do	13	29 S.	23 E.	60	0	349	215	25	290	690	320	340	N. C.	35	High	..do	Bad	Do.
Do	..do	13	29 S.	23 E.	(b)	Tr.	24	5	325	88	580	120	540	C.	6.2	..do	Na-Cl	Very bad	Fair.
Southern Pacific Co	..do	24	29 S.	23 E.	101	0	380	140	25	360	600	390	180	?	50	..do	Ca-CO_3	Poor	Good.
D. Ralls	Dec. 8	28	29 S.	23 E.	756	6	22	5	140	42	310	90	260	N. C.	14	Moderate	Na-Cl	Fair	Fair.
W. Steiman	Dec. 6	26	25 S.	24 E.	995	15	41	5	15	5	140	60	110	N. C.	20	Low	Na-CO_3	Good	Oood.
A. H. Dewitt	..do	27	25 S.	24 E.	600	12	54	5	15	19	150	70	90	N. C.	25	..do	..do	..do	Do.
Mrs. H. Carlson	..do	28	25 S.	24 E.	300	12	50	5	15	14	140	60	90	N. C.	25	..do	..do	..do	Do.
C. A. Sayre	..do	30	25 S.	24 E.	740	18	40	5	15	6	150	60	110	N. C.	20	..do	..do	..do	Do.
J. Hamlin	..do	34	25 S.	24 E.	80	0	192	146	40	150	480	180	290	N. C.	30	Moderato	Na-SO_4	Bad	Do.
Do	..do	34	25 S.	24 E.	647	15	39	5	15	17	140	70	90	N. C.	25	Low	Na-CO_3	Good	Do.
Kern County Land Co	Nov. 28	8	27 S.	24 E.	890	12	41	5	10	28	130	80	50	N. C.	45	..do	..do	..do	Do.
A. W. Thresher	..do	12	27 S.	24 E.	54	0	86	52	150	315	420	340	30	C.	14	Moderate	Ca-Cl	Poor	Fair.
Tracy Bros	Dec. 4	31	28 S.	24 E.	50	6	40	5	15	27	120	80	50	N. C.	50	Low	Na-CO_3	Good	Good.
Do	..do	32	28 S.	24 E.	567	12	40	Tr.	15	10	130	60	80	N. C.	25	..do	..do	..do	Do.
Do	..do	32	28 S.	24 E.	850	12	32	Tr.	30	16	150	70	90	N. C.	25	..do	..do	..do	Do.
	..do	6	29 S.	24 E.	20	0	153	113	80	116	460	150	320	N. C.	20	Moderate	..do	Bad	Do.
Miller & Lux	..do	30	29 S.	24 E.	40	0	185	140	35	210	450	240	190	?	40	..do	..do	Poor	Do.
Mrs. A. Desmond	Nov. 27	10	25 S.	25 E.	18	0	372	711	125	570	1,600	600	900	?	10	High	Na-SO_4	Very bad	Fair.
A. S. Porter	..do	10	25 S.	25 E.	(c)	0	139	20	35	154	260	200	40	?	60	Moderate	Ca-CO_3	Fair	Good.
W. J. Browning	..do	11	25 S.	25 E.	43	0	112	76	75	246	380	300	40	?	27	..do	Ca-Cl	Poor	Do.
C. F. McHarvey	..do	11	25 S.	25 E.	90	0	135	46	40	206	300	260	15	?	50	..do	Ca-CO_3	..do	Do.
T. B. Orr	..do	11	25 S.	25 E.	105	0	139	20	30	135	250	180	50	?	70	..do	..do	Fair	Do.
Southern Pacific Co	..do	11	25 S.	25 E.	220	0	89	20	50	96	240	150	90	?	40	..do	..do	..do	Do.
Pacific Coast Oil Co	Dec. 6	31	25 S.	25 E.	700	15	39	5	10	21	130	70	80	N. C.	25	Low	Na-CO_3	Good	Do.
Kern County Land Co	Nov. 28	3	27 S.	25 E.	105	0	416	58	20	256	510	290	230	N. C.	12	High	..do	Poor	Fair.
W. H. Smith	..do	4	27 S.	25 E.	72	0	375	37	20	182	440	230	260	N. C.	9	Moderate	..do	..do	Do.
W. Hubbard	Nov. 30	2	25 S.	26 E.	180	0	109	Tr.	20	45	180	100	90	N. C.	25	..do	..do	Fair	Good.
C. C. Albert	..do	6	25 S.	26 E.	80	0	134	5	25	75	210	120	110	N. C.	20	..do	..do	..do	Do.
J. D. Smith	..do	10	25 S.	26 E.	150	6	90	5	25	34	180	80	120	N. C.	20	..do	..do	Good	Do.
Southern Pacific Co	Nov. 29	7	27 S.	26 E.	119	0	101	10	10	66	170	120	50	N. C.	55	..do	Ca-CO_3	Fair	Do.
R. Orcier	..do	7	27 S.	26 E.	175	0	100	5	10	79	160	130	30	N. C.	140	..do	..do	..do	Do.
H. C. Phillips	..do	22	27 S.	26 E.	50	0	160	10	15	121	230	170	50	N. C.	60	..do	..do	..do	Do.
W. W. Kaye	..do	23	27 S.	26 E.	142	0	121	5	15	85	180	140	50	N. C.	50	..do	..do	..do	Do.
J. Zumwaldt	Dec. 1	6	31 S.	27 E.	59	0	106	5	10	71	160	120	50	N. C.	55	..do	..do	..do	Do.
Kern County Land Co	..do	19	31 S.	27 E.	1,395	Tr.	102	34	15	39	210	90	130	N. C.	20	..do	Na-CO_3	Good	Do.
W. R. Shafter	..do	24	31 S.	27 E.	620	Tr.	104	30	15	41	210	90	130	N. C.	20	..do	..do	..do	Do.
Louis Schmidt	..do	28	31 S.	27 E.	58	0	98	5	5	71	150	120	30	N. C.	110	Low	Ca-CO_3	Fair	Do.
Miller & Lux	..do	6	32 S.	27 E.	75	0	106	20	15	43	190	90	120	N. C.	20	Moderate	Na-CO_3	Good	Do.
Kern County Land Co	..do	8	32 S.	27 E.	378	0	150	67	25	97	320	150	180	N. C.	25	..do	..do	Fair	Do.
Do	..do	16	32 S.	27 E.	648	0	109	115	25	127	350	180	160	?	55	..do	Na-SO_4	..do	Do.
Do	..do	21	32 S.	27 E.	896	0	143	60	25	120	300	170	140	N. C.	40	..do	Na-CO_3	..do	Do.
Associated Oil Co	Dec. 2	32	28 S.	28 E.	1,052	......	......	Tr.	20	310	......	360	......	......	......	......	......	......	
Petroleum Development Co	..do	4	29 S.	28 E.	[d]5,135	0	132	5	15,100	2,300	25,000	2,300	26,000	C.	.1	Very high	Na-Cl	Very bad	Bad.
Do	..do	4	29 S.	28 E.	[d]5,135	18	1,710	5	1,380	59	3,800	90	4,500	N. C.	.5	..do	..do	..do	Do.
Associated Oil Co	..do	5	29 S.	28 E.	(e)	0	104	5	15	54	170	100	80	N. C.	30	Moderate	Na-CO_3	Fair	Good.
Do	..do	5	29 S.	28 E.	942	......	......	Tr.	25	340	......	390	......	......	......	......	......	......	
Pacific Coast Oil Co	..do	7	29 S.	28 E.	200	0	98	10	10	54	160	100	60	N. C.	40	Moderate	Na-CO_3	Fair	Do.
James Land	Dec. 1	6	30 S.	28 E.	56	0	86	Tr.	10	57	140	110	40	N. C.	55	Low	Ca-CO_3	..do	Do.
C. T. Planz	..do	7	30 S.	28 E.	42	0	106	15	15	82	190	130	50	N. C.	75	Moderate	..do	..do	Do.
Fairfax school district	Dec. 3	11	30 S.	28 E.	100	0	144	125	285	500	800	530	200	C.	7	High	Ca-Cl	Bad	Fair.
Peter Muil	..do	12	30 S.	28 E.	125	0	204	408	185	750	1,100	780	140	C.	11	..do	Ca-SO_4	Very bad	Do.
C. F. Haperkern	Dec. 1	18	30 S.	28 E.	72	0	116	5	10	90	170	140	30	N. C.	100	Moderate	Ca-CO_3	Fair	Good.
J. P. Chinetti	Dec. 3	24	30 S.	28 E.	51	0	245	760	450	1,080	2,100	1,100	740	C.	4.5	Very high	Ca-SO_4	Very bad	Poor.
Peter Gilli	Dec. 1	30	30 S.	28 E.	104	0	102	5	10	76	160	130	30	N. C.	90	Moderate	Ca-CO_3	Fair	Good.
Toni Harris	..do	30	30 S.	28 E.	160	0	122	Tr.	10	79	170	130	50	N. C.	40	..do	..do	..do	Do.
R. E. Houghton	..do	7	31 S.	28 E.	400	0	188	43	25	150	320	200	110	N. C.	50	..do	..do	..do	Do.
F. A. Langdon	Dec. 3	12	31 S.	28 E.	240	0	222	56	25	180	360	210	140	N. C.	35	..do	..do	Poor	Do.
Mrs. M. Johnson	Dec. 1	19	31 S.	28 E.	80	0	119	25	20	64	220	110	120	N. C.	25	..do	Na-CO_3	Fair	Do.
Mountain View school district	Dec. 3	31	30 S.	29 E.	40	0	222	20	15	96	300	150	180	N. C.	13	..do	..do	..do	Fair.
Towne ranch	..do	19	31 S.	29 E.	60	0	218	88	55	190	440	220	220	N. C.	30	..do	..do	Poor	Good.
Do	..do	19	31 S.	29 E.	140	0	208	136	80	184	540	210	320	N. C.	20	High	..do	..do	Do.

[a] C., corrosive; N. C., noncorrosive; ?, corrosion uncertain or doubtful.
[b] Artesian well depth unknown; probably more than 400 feet.
[c] Two wells 108 and 118 feet deep.
[d] The 9⅝-inch casing is landed at 2,609 feet and the 11⅝-inch casing at 1,030 feet. The first sample is the water that comes out between these casings and the second is from the bottom of the well.
[e] Seven wells 400 to 405 feet deep.

TABLE 61.—*Mineral analyses of ground waters in Kern County.*

[Parts per million except as otherwise designated.]

Owner.	Date.	Location. Sec.	T.	R.	Depth of well (feet).	Determined quantities. Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Computed quantities. Scale-forming ingredients (s).	Foaming ingredients (f).	Probability of corrosion (c).[a]	Alkali coefficient (k) (inches).	Classification. Mineral content.	Chemical character.	Quality for boilers.	Quality for irrigation.	Analyst.
J. P. Irish	Nov. 28, 1910	8	27 S.	23 E.	480	......	0.10	8.5	1.6	[b]95	12	67	0	112	312	80	260	N.C.	11	Moderate	Na-Cl	Bad	Fair	F. M. Eaton.
Southern Pacific Co	Nov. 30, 1892	18	29 S.	23 E.	686	[c]19	......	37	......	161	0	26	49	261	540	[d]140	430	?	8	High	..do	..do	..do	Southern Pacific Co.
Do	......	11	25 S.	25 E.	125	[c]69	......	42	6	49	0	120	51	29	354	200	130	?	35	Moderate	Ca-CO_3	Fair	Good	Do.
Do	July 23, 1910	11	25 S.	25 E.	220	[c]78	......	39	5	50	0	92	66	68	351	200	140	?	30	..do	Ca-SO_4	..do	..do	Do.
Do	Nov. 27, 1910	11	25 S.	25 E.	220	......	.35	41	4.8	[b]40	0	90	66	48	364	180	110	?	40	..do	..do	..do	..do	F. M. Eaton.
Do	May 30, 1902	7	27 S.	26 E.	112	[c]29	......	27	5	18	0	100	16	18	163	120	50	?	100	..do	Ca-CO_3	..do	..do	Southern Pacific Co.
Williams & Noyer	Nov. 29, 1910	7	27 S.	26 E.	120	......	.30	27	5.3	[b]11	0	105	18	6.0	171	140	30	N.C.	250	..do	..do	..do	..do	F. M. Eaton.
Southern Pacific Co	Sept. 15, 1892	16	30 S.	26 E.	134	[c]25	......	42	5	26	0	118	55	23	234	160	70	?	75	..do	..do	..do	..do	Southern Pacific Co.
Do	Aug. 11, 1903	24	29 S.	27 E.	(e)	[c]19	......	22	2	23	0	102	14	11	142	90	60	N.C.	50	Low	..do	Good	..do	Do.
Do	Nov. 29, 1910	24	29 S.	27 E.	(e)	[c]24	......	88	11	60	0	150	184	58	499	300	160	?	30	Moderate	Ca-SO_4	Poor	..do	Do.
P. M. Wilkerson	Dec. 1, 1910	36	30 S.	27 E.	52	......	.35	30	6.2	[b]13	0	117	19	9.0	175	150	35	N.C.	180	..do	Ca-CO_3	Fair	..do	F. M. Eaton.
Kern County Land Co	..do	20	31 S.	27 E.	650	......	.10	13	1.8	[b]49	Tr.	105	44	11	218	90	130	N.C.	25	..do	Na-CO_3	Good	..do	Do.
Southern Pacific Co	Mar. 13, 1902	3	29 S.	28 E.	18	[c]30	......	46	8	47	0	248	6	30	289	180	130	N.C.	19	..do	Ca-CO_3	Fair	..do	Southern Pacific Co.
Petroleum Development Co.	Dec. 2, 1910	4	29 S.	28 E.	[f]5,135	......	.05	10	1.2	[b]1,550	0	1,708	0	1,418	3,930	60	4,200	N.C.	.6	Very high	Na-Cl	Very bad	Bad	F. M. Eaton.
Pacific Coast Oil Co	......	7	29 S.	28 E.	200	[c]26	......	18	7	14	0	84	27	1	134	90	40	N.C.	40	Low	Ca-CO_3	Good	Good	Pacific Coast Oil Co.
E. A. Marriott	Dec. 3, 1910	29	30 S.	29 E.	284	......	.35	61	18	[b]43	0	278	51	28	372	260	110	N.C.	60	Moderate	..do	Poor	..do	F. M. Eaton.

[a] C, corrosive; N.C., noncorrosive; ?, corrosion uncertain or doubtful.
[b] Computed.
[c] Includes oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$).
[d] Approximate.
[e] Wells at Bakersfield roundhouse.
[f] From bottom of well.

Such detailed facts about the various types of wells in Kern County as have been secured by the Geological Survey are assembled in the following table. The data were collected in large part by A. J. Fiske, jr.

TABLE 62.—*Records of wells in Kern County.*

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.[a]	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
Miller & Lux	11	25	21		Bored, 8 inches		0	78	Artesian	S	26		
Fred Cox	20	25	22	1901	Bored, 14 inches	800	0	78	do	D, S, I	[b] 262	$3,000.00	
Miller & Lux	4	25	22		Bored, 8 inches	250	0	74	do	D, S, I	11		
Fred Cox	23	25	22		Bored, 7 inches		0	75	do	S	2		
Miller & Lux	3	25	23		Bored, 8 inches		0	74	do	S	28		
Mr. Haley	1	25	23		do		0	70	do	I	60		
	12	25	23		Bored, 10 inches		0	70	do	N	75		
	7	25	24		Bored, 6 inches		0	70	do	N	3		
Mr. Dorsey	10	25	24		Bored, 8 inches		0	71	do	I, S	22		
	2	25	24		do		0	71	do	N	68		
C. H. Dorsey	4	25	25	1891	Bored, 7 inches	45	14		Wind	I		45.00	$100
W. B. Timmins	10	25	25	1901	Bored, 8 inches	80	18		do	D, S, I		1.00	52
B. Thomas	3	25	25	1902	Bored, 10 inches	132	29		Gas	I	44	125.00	85
Do	3	25	25		do	56	29						
Teresa Panero	10	25	25		Dug, 3 feet by 3 feet.	18	17	66	Wind	D, S		25.00	50
Margereta Pulvan	15	25	25		Bored, 6 inches	20	16?		Hand	D		20.00	5
C. Conteras	10	25	25		Bored	25	19	68	do	D			
C. F. McHarvey	11	25	25		Bored, 8 inches	90?	30?		Wind	S			25
Mr. Mallery	1	25	25	1889	Bored, 6 inches	70	32		Wind, horse	D		51.00	200
J. L. Williams	6	25	26	1890	Bored, 8 inches	100	65		Wind	D, S		122.50	35
C. C. Albert	6	25	25	1898	Bored, 7 inches	80	65	61	do	D, S		100.00	60
Virgil Starwalt	8	25	26		do		70?		Not raised	N			
Victor Vieux	8	25	26	1902	do	80?	65?		Wind	D			100
Angelo Pecci	10	25	26		do	130?	115?		do	N			115
J. D. Smith	10	25	26	1887	do	150?	125?		do	N		135.00	115
John Vanlone	10	25	26	1888	do	140?	125?		do	D		140.00	87
Reed estate	2	25	26	1889	do	148	132		Horse	S			

[a] D, domestic; S, stock; I, irrigation; B, boilers; N, not used.

[b] Yield estimated or statement of owner taken.

TABLE 62.—*Records of wells in Kern County*—Continued.

Owner.	Location. Section.	Town-ship south.	Range east.	Year com-pleted.	Type and diameter of well.	Depth of well.	Depth to water level	Tem-pera-ture of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of ma-chinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
W. Hubbard	2	25	26	1890	Bored, 7 inches	172?	156	56	Horse	D, S	1	$160.00	$75
Mrs. Wm. Moman	26	25	26	1905	Bored, 8 inches	200?	160?		do	S		300.00	100
Chas. Albert	34	25	26	1889	do	155?	131?		Wind	D, I		180.00	120
Do	34	25	26	1898	do	160?	132?		do	D, I		117.00	75
Frank Gomez	32	25	26		Bored, 6 inches	90?	66?		Horse	D			50
Henry Vieaux	20	25	26		Bored, 8 inches		53		do	D			50
W. Steiman	26	25	24	1890	Bored, 10 inches	995?	0	82	Artesian	N	4		
A. H. DeWitt	37	25	24	1895	Bored, 9 inches	660?	0	78	do	I	11		
Mrs. H. Carlson	28	25	24	1892	Bored, 5 inches	300?	0	76	do	N	1		
C. A. Sayre	30	25	24	1890	Bored, 9 inches	430?	0	77	do	I		900.00	
Do	30	25	25	1894	Bored, 16 inches	740?	0	70	do	I	116		
	20	25	24		Bored, 7 inches		0	70	do	S			
	20	25	24		do		0	70	do	N	8		
Chas. Reynolds	22	25	24		do		0	72	do		25		
Geo. H. Lawrence	22	25	24	1895	Bored, 12 inches	600	0	73	do	I	13	2,400.00	
Do	22	25	24		Bored, 6 inches	55	13?	64	Hand	D		45.00	5
Jeptha Beebe	23	25	24	1891?	Bored, 8 inches		14		Wind	I		40.00	66
	23	25	24		do		0	71	Artesian	I	Small.		
H. Wilson	26	25	23		do		0	79	do	D, S			
E. Brown	27	25	23		Bored, 10 inches		0	78	do	I			
T. A. Raymond	33	25	23	1884	Bored, 9 inches	340	0	78	do	S	26		
C. Clayton	4	26	23		do		0	78	do	S	13		
T. A. Raymond	31	25	23		Bored, 6 inches	340?	0	80	do	N	18		
F. W. G. Morebus	6	26	23		Bored, 9 inches		0	79	do	N	18		
T. C. Cowen	4	26	24	1890	Bored, 8 inches	500?	0	81	do	I	31		
Hamilton school district	33	25	24	1899	Bored, 6 inches	300	0	66	do	D	1		
W. B. Newman	3	26	24	1899	Bored, 5 inches	275	0	68	do	D	2		
J. Hamlin	34	25	24	1899	Bored, 6 inches	290	0	74	do	D	2		
Do	34	25	24	1901	Bored, 10 inches	647	0	78	do	I	20	800.00	
R. J. Green	3	26	24		Bored, 8 inches	500	0	80	Gas, artesian	I			
Kern County Land Co.	11	26	24		do	1,000		82	Horse	S			
Pacific Coast Oil Co.	31	25	25	1902	do	700	18	79	Compressed air	B	14		
Kern County Land Co.	16	26	25	1903	Bored, 10 inches	46	15	72	Gas	S			
F. S. Benson	14	26	25		Bored, 7 inches	46	22	67	Wind	D		35.00	100
J. L. Robertson	2	26	25	1904	Bored, 10 inches	100	20?		Steam	I		100.00	800
Nathan Smith	1	26	25	1891	Bored, 7 inches	80?	30?		Wind	D		60.00	100
L. Robertson	9	25	27	1901	Bored, 10 inches	283	194		do	D, S			

W. L. Smith	9	26	27	1890	Bored, 8 inches	400	270?		Horse	D, S		1,000.00	300
	20	26	26		do	100+	96		Wind	N			100
H. L. Taylor	20	26	26		Bored, 6 inches	84	64?		do	D		60.00	100
C. E. Kitchen	29	26	26	1894	do	120	80?		do	D		600.00	
Robertson school district	29	26	26		do	125	95?		do	D		94.00	100
H. E. Philips	32	26	26	1902	Bored, 8 inches	144	90?		do	D		144.00	100
Kern County Land Co	31	26	26		Bored, 7 inches	83	65		Horse	D		60.00	75
G. L. Robertson	24	26	25	1889	Bored, 8 inches	65	20?	67	Wind	D		65.00	70
Mrs. Susan L. Beebe	14	26	25		Bored, 6 inches	82	35?		do	D		60.00	100
Kern County Land Co	26	26	25	1886	do	93	35?		do	D		69.00	100
Do	23	26	25	1903	Bored, 10 inches	89	23	69	Gas				
Do	22	26	25	1904	do		12	64	do	S			
Do	21	26	25		Bored, 6 inches	82	26	66	Wind	D			
Do	27	26	25	1903	Bored, 10 inches	80	26		Gas	S			
Do	29	26	25	1903	do	75	20		do	S			
Do	17	26	24		Bored, 8 inches	512	0	79	Artesian	S	31		
Do	19	26	24		Bored, 10 inches	480	0	78	do	S	52		
R. B. Johnson	34	26	23	1886?	Bored, 8 inches	369	0	78	do	S, I	56		
C. J. Clayton	32	26	23	1885	Bored, 10 inches	284	0	78	do	S	119		
J. D. Wells	34	26	22	1885	Bored, 8 inches	320		76	Gas	I	89		900
T. W. Brown	34	26	22	1886	do	470	0		Artesian	I	10		
Do	34	26	22	1901	do	700	0		Gas; artesian	I	5	1,000.00	1,000
W. Y. Horner	2	27	22	1884	do	599	5		Gas	I	133		a 1,175
Paige & Montgomery	6	27	23		do	800	0	82	Gas; artesian	I	67		
Mr. Brown	5	27	23		do		0	76	Artesian	I, S	8		
Mrs. O'Brien	9	27	23	1889	do	360	0		do	N	Small.		
Mrs. C. Davis	4	27	23	1884	do	234	0	76	do	N	b 10		
.P. Irish	8	27	23	1895	do	480	7		Gas	I	133		a 1,650
Do	8	27	23	1889	Bored, 9 inches	1,150	2		Not raised	N			
Harry Rambow	10	27	23	1888	Bored, 8 inches	423	0	76	Artesian	D, S, I	6		
Kern County Land Co	2	27	23		Bored, 7 inches		0	76	do	S	b 35		
Do	12	27	23		Bored, 8 inches	533	0		do	S			
Do	8	27	24		Bored, 10 inches	890	0		Not raised				
	10	27	24		do		17		Wind, hand, gas	D, S			
Do	6	27	25	1903	do	86	20	70	Gas				
J. McCombs	8	27	25		Bored, 7 inches	89	29	64	Wind	D			
Kern County Land Co	17	27	25	1903	Bored, 10 inches	124	40	71	Gas	S			
Do	4	27	25		do	90		72	do	S			
N. Root	4	27	25	1895	Bored, 6 inches	77	27	65	Wind	D			
W. H. Smith	4	27	25	1898	do	72	24	63	do	D			
Kern County Land Co	3	27	25		Bored, 10 inches	700	24	78	Gas	D, S			
Eli Bonnet	7	27	26	1905	Bored, 8 inches	120	69?		do	D		120.00	
H. E. Philips	23	27	26	1905	Bored, 7⅝ inches	142	105?		Horse	S		135.00	40
Pacific Coast Oil Co.[c]	32	27	26	1905	Bored, 8 inches	265	143		Steam	B			
Southern Pacific Co	15	28	26	1890?	do	150	130?		Hand	D			
Kern County Land Co	28	27	25	1903	Bored, 10 inches	137	36	70	Gas	S			
Do	29	27	25	1903	do	198	26	76	do	S			
Delta school district	19	27	25		Bored, 6 inches	130	24	68	Hand	D			
A. Filben	18	27	25	1905	Bored, 10 inches	56	24	72	Gas	D	11	65.00	250
Palm Fruit Co	25	27	24		Bored, 12 inches	80	20	72	do	I	15		
H. L. Weems	30	27	25		Bored, 6 inches	65	17		Wind	D, S			

a Cost of well and equipment combined.

b Yield estimated or statement of owner taken.

c Two wells.

TABLE 62.—*Records of wells in Kern County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
Kern County Land Co.	6	28	25	1903	Bored, 10 inches	132	18	71	Gas	S			
Do	5	28	25	1903	do			71	do	S			
C. W. Rowlee	4	28	23	1901	do	660+	0		Artesian	I	188		
Kern County Land Co.	5	28	23	1899	Bored, 13 inches	600+	0	76	do	I	104		
Do	5	28	23	1900?	do	600+	0		do	I	70		
Do	5	28	23	1900	do	600+	0		do	I	70		
Sisson & Son	24	28	23	1900	Bored, 11 inches	600+	0		do	I	160		
Mrs. E. Lewis	24	28	23	1892	Bored, 9 inches	390	0	76	do	S, I	46		
P. Salis	25	28	23	1897	do	444	0		do	I	4	$800.00	
C. B. Crawford	25	28	23	1904	Bored, 10 inches	450	0	73	do	I	30		
H. F. Laird	31	28	24	1898	Bored, 9 inches	425	0		do	I	18	1,000.00	
Tracy Bros.	32	28	24	1893	do	567	0		do	I	92	1,250.00	
Do	32	28	24	1904	Bored, 11 inches	850	0		do	I	28	2,100.00	
G. E. Stimson	32	28	24	1895	Bored, 9 inches	425	0		do	I	46	1,000.00	
Tracy Bros.	5	29	24	1901	Bored, 11 inches	757	0		do	I	45	2,100.00	
Miller & Lux	9	29	23		Bored, 7 inches	85	13		Horse	D, S			
Southern Pacific Co.	18	29	23	1892	Bored, 8 inches	600		67	Steam	B			
Miller & Lux	27	29	23		do	85	10?	68	Horse	D, S			
Southern Pacific Co.	24	29	23	1891	Bored, 7 inches	101	23	67	Hand	D			
Miller & Lux	13	29	23		Bored, 12 inches		0	76	Artesian	I	43		
Do	30	29	24		Bored, 13 inches	800	20	67	Hand	D, S			
Do	30	29	24		Bored, 7 inches	40	5		Not raised	N			
Do	9	30	24		do	70	9		do	N			
Kern County Land Co.	7	30	25		Bored, 8 inches	42	12		Horse	S			
Do	18	30	25		do	45	2		do	S			
Do	7	30	25	1899	Bored, 13 inches	90	8		Electric	D, S	11		
Do	3	30	25	1904	Bored, 6 inches	87	15	64	Horse	D, S			
Do	32	29	25	1893	do	48	16		do	S			
A. Freeley	34	29	25		do	71	20	66	do	D, S			
Kern County Land Co.	3	30	25	1904	do	46	15		do	S			
J. Enos	2	30	25	1895	do	70	16	62	Hand	D			
Rio Bravo Vineyard Co.	27	29	25		Bored, 7 inches	80	17		Not raised	N			
J. O. McClellan	24	29	25		Bored, 13 inches	80	15?		Steam	I	*a* 200	100.00	$1,000
H. H. Schultz	14	29	25	1905	do	94	} 16		do	I	250		
Do.[b]	14	29	25	1905	do	60							
Do	12	29	25	1895	do	96	18		do	I	227		
Kern County Land Co.	5	29	26		Bored, 8 inches	61	6		Not raised	N		50.00	
Do	17	29	26		Bored, 7 inches		12		Horse	D, S			50

Do	9	29	26		do		7	67	do	S			
G. T. Nighbert	32	28	26	1905	Bored, 13 inches	102	17		Steam	I	50		
E. A. David	21	29	26	1891	Bored, 6 inches	40	11	68	Horse	D, S			
Mr. George	15	29	26		do	75	11	68	Hand	D, S			
James Arthur	15	29	26		Bored, 7 inches	60	12	67	do	D, S			
Palm school district	15	29	26		Bored, 6 inches	44	7	72	do	D			
G. W. Michel	16	29	26		do	80	10		Wind, hand	D, S			
Kern County Land Co.?	15	29	26		Bored, 7 inches	65	12	71	Hand	S			
Kern County Land Co	10	29	26		Bored, 8 inches	39	31		Horse	S		30.00	
W. H. Baker	11	29	26	1897	Bored, 6 inches	40	20	71	Hand	D			
Kern County Land Co	26	28	26		Bored, 7 inches	100+	40		Not raised	N			
Do	25	28	26		Bored, 8 inches	51	31		do	N		45.00	
Do	1	29	26		Bored, 7 inches		19		Horse	D			
J. C. Roberts	6	29	27	1893	Bored, 6 inches	65	25		Hand	N			
Norris school district	8	29	27		Bored, 8 inches	36	25		do	D			
S. G. Rex	8	29	27	1889	Bored, 6 inches	82	23	69	do	D, S			
W. J. Heath	9	29	27		do	80	22?	69	do	D			
Kern County Land Co	14	29	27		Bored, 8 inches	82	28		Wind	D, S			
J M. McIntosh	14	29	27	1905	Bored, 10 inches	55	35	70	Hand	D			
Mrs. M. Nichols	13	29	27		Dug, 4 feet	29	24		Wind	D, S			
T. A. Wells	12	29	27	1902	Dug, 3 by 6 feet	72	67		Gas	D, S			
Eastern Consolidated Oil Co	12	29	27	1903	(c)	71	56		Steam	B	26		
J. A. Montgomery	12	29	27	1905	(d)	122	84		Gas	I			
Monte Cristo Oil Co e	5	29	28	1903	Bored, 9⅝ inches	280 320	180 210		Steam	B			
Pacific Coast Oil Co	7	29	28	1901	Bored, 14 inches	200	40		do	D, I	a 12		
Associated Oil Co. f	34	28	28	1900	Bored, 13 inches	80	10		do	B	a 4		
Do	34	28	28	1900	do	40							
Do	34	28	28	1900	do	35							
Do	34	28	28	1900	do	30							
Miller & Lux	1	29	28		Bored, 10 inches		0	90	Artesian	N	35		
J. Barker	5	29	29	1893	Bored, 6 inches	1,300	0	87	do	N	2		
Do	5	29	29	1893	Bored, 10 inches	400	0	92	do	N	30		
E. S. Jewett	18	29	28		Dug, 4 by 4 feet	22	20		Not raised	N			
E. M. Roberts g	13	29	27	1898	Bored, 15 inches	30	8		Steam	I	250		h 3,000
Do. i	13	29	27	1902	do	40	6		do	I	350		2,500
Do	13	29	27	1878	Bored, 12 inches	30	18		Gas	D			140
Mrs. M. Owmans	19	29	28		Bored, 6 inches	27	5	69	Hand	D			
Union Ice Co	19	29	28	1903	Bored	36	13	68	Steam	Ice	a 23		
Sumner Water Co	21	29	28	1893	Dug, 7 by 9 feet; bored, 10 inches.	400	100		do	D	55		
C. C. Pierce	23	29	27	1888	Bored, 6 inches	23	8	68	Hand	D, S			
C. E. Greeley	23	29	27	1893	Bored, 7 inches	30	5		Horse	D			
Kern County Land Co. i	22	29	27	1898	Bored, 13 inches	51	3		Electric	I	200		
D. M. Elliott	21	29	27	1893	Bored, 6 inches	61	14	62	Hand	D			
J. O. Bolender	21	29	27		Bored, 7 inches	35	10	68	do	D			
Kern County Land Co	16	29	27		Bored, 13 inches	57	23		Horse	S		55.00	57
N. Peters	21	29	27	1894	Bored, 6 inches	61	24		Hand	D, S			

a Yield estimated or statement of owner taken.
b Two wells.
c Dug 56 feet and bored 15 feet by 10 inches diameter.
d Dug 74 feet and bored 48 feet by 9⅝ inches diameter.
e Three wells.
f Four wells.
g Nine wells.
h Cost of well and equipment combined.
i Five wells.

TABLE 62.—*Records of wells in Kern County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
Kern County Land Co.	20	29	27		Bored, 6 inches	35	8	64	Hand	D			
Do.[a]	20	29	27	1899	Bored, 13 inches	90	13		Electric	I	175		
Do.[a]	17	29	27	1899	do	120	16		do	I	250		$3,500
Do.	17	29	27	1892	Bored, 7 inches	76	14	69	Gas	D	1		
J. G. Deriw	19	29	27	1903	Bored, 6 inches	50	9		Wind	D			
Hans Madson	19	29	27	1904	do	36	9	68	Wind, hand	D, S			
F. D. Lowe	19	29	27	1904	Bored, 10 inches	50	8	68	Hand	D			
M. F. Clandino	19	29	27	1904	Bored, 7 inches	20	9	68	do	D, S			
Mrs. C. B. McCleod	19	29	27	1894	Bored, 10 inches	48	16	69	Wind, hand	D, S			
Solomon Jewett	18	29	27		Bored, 6 inches	33	8		Hand	D, S			
Edward Wright	13	29	26		Bored, 7 inches	68	12	68	do	D			
A. E. Burr	13	29	26	1895	do				Wind	D			
Kern County Land Co.[a]	14	29	26	1900	Bored, 13 inches	107	16		Electric	I	275		
Mrs. Johnson	22	29	26		Bored, 6 inches	75	14		Wind	D, S			
L. G. Helm	23	29	26	1891?	do	64	17		Hand	S			4
G. Meuser	23	29	26		do	60	7?	67	do	D		$45.00	3
E. F. Beck	21	29	26		Bored	60	10?	64	do	D		45.00	4
John Karr	21	29	26		do	55	10	64	do	D		40.00	4
Antonio Wegis	28	29	26		Bored, 6 inches	90	12?	66	Horse	D		70.00	25
John Frey	29	29	26	1905	Bored, 8 inches	27	13		do	D		40.00	100
I. W. Harbaugh	29	29	26	1899	do	46	15		Hand	D		46.00	75
S. B. Kingsley	26	29	26		Bored, 6 inches	39	13		Steam	D		30.00	450
Wiley Smith	26	29	26	1897	Bored, 8 inches	49	10	67	Hand	D, S			
B. T. Dewey	26	29	26	1901	Bored, 12 inches	80	8		Electric	I	225		[b] 3,500
Mr. Kelso	25	29	26		Bored, 6 inches	35	8	68	Hand	D, S			
Kern County Land Co.[a]	30	29	27	1901	Bored, 13 inches	115	16		Electric	I	200	50.00	
W. E. Dargie[c]	30	29	27	1904	do	148	6		do	I			3,500
Do	30	29	27	1904	Bored, 10 inches	148	6						
Do	30	29	27	1901	Bored, 12 inches	98	8		do	I	250		[b] 3,000
P. D. Jewett[d]	32	29	27	1904	Bored, 13 inches	80	7		do	I	250		
Kern County Land Co.[a]	29	29	27	1901	do	87	11		do	I	200		
Do	29	29	27	1898	do	69	9		do	I	150		
Do.[c]	29	29	27	1898	do	71	9		do	I	200		
Do.[d]	34	29	27	1900	do	71	1		do	I	200		
Do.[a]	34	29	27	1897	do	61	10		do	I	187		
Do.[a]	34	29	27	1898	do	70	7		do	I	175		
Do	26	29	27	1899	do	69	5		do	I	187		
Do	34	29	27		Bored, 10 inches	86	8		Horse	D			

W. Winter	35	29	27	1904	Bored, 6 inches	20	4	60	Hand	D			
D. D. Hill	36	29	27		do	35	7	62	do	D			
C. C. Stockton	36	29	27	1890	Bored, 8 inches	45	8	62	Wind	D			
A. C. Tibbett	36	29	27		Bored, 6 inches	41	3	62	Hand	D, S			
D. R. Miller	1	30	27	1902	do	40	12	62	do	D, S		40.00	
James Lamb	6	30	28	1893	do	56	4	60	do	D			
Electric Water Co.[e]	25	29	27	1899	Bored, 13 inches	56	12		Electric	D	67		
Do	30	29	28		do	58	10		do	D	67		
Do	25	29	27	1902	do	56	8		do	D	67		
Do.[e]	30	29	28	1901	do	58	10		do	D	67		
Do	30	29	28	1904	do	66	4		do	D	67		
Do	30	29	28	1904	do	66	10		do	D	67		
Do	31	29	28	1903	do	56	10		do	D	67		
T. P. Pinnell	32	29	28	1897	Bored, 6 inches	39	24?		Wind	D			
Sumner Water Co	29	29	28	1903	Bored, 10 inches	175	26	68	Steam	D	74	300.00	
Mr. Patent	28	29	28		Bored, 6 inches	70	30		Not raised	N			
Chamberlin Canning Co	28	29	28		do	60	30		Wind, steam	D			
Chas. Offer	27	29	28	1896	Bored, 10 inches	90	30		Steam	I.	150		
Do	27	29	28	1896	do	170	30						
Kern Fruit and Berry Co	28	29	28	1904	do	110	80	76	Gas	I.	11		?1,150
Frank Morrison	34	29	28	1896?	Bored, 6 inches	45	31		Not raised	N			
H. A. Bobby	35	29	28		do	250	23	74	Wind	D, S			
Mrs. E. C. Morley	35	29	28	1901	Bored, 4 inches	240	27	73	Gas	D		300.00	150
Mr. Sturdevant	36	29	28		Bored, 8 inches	61	36	64	Hand	N		50.00	8
H. J. Neikirk	35	29	28	1898	Bored, 2¼ inches	84	34?	65	Horse	D, S		46.00	10
J. F. Buckles	1	30	28		Bored, 6 inches	80	35		do	D		60.00	25
C. E. Hess	34	29	28		Bored, 13 inches	96	15		Not raised	N		375.00	
Mrs. E. C. Scott	34	29	28	1897	Bored, 5 inches	75	12		Hand	N			
A. J. Owens	33	29	28	1905	Bored, 8 inches	85	14	66	do	D		65.00	4
J. T. Bayse	33	29	28	1892	Bored, 6 inches	125	20?	64	Wind	D		138.00	35
Cemetery	32	29	28		do	73	10	74	Electric	I.			
A. Amourig	5	30	28	1895	Bored, 5 inches	85	9.5		Hand	D, S			
D. Mungai	32	29	28	1904	Bored, 8 inches	40	8		Horse	D, I		30.00	80
Mrs. Wildman	6	30	28		Bored, 7 inches	60	14	67	Wind, hand	D, S			
Wm. Baker	6	30	28	1900?	Bored, 8 inches	112	17	66	do	D, S			
J. W. Overall	8	30	28	1892?	Bored, 6 inches	66	15	64	Hand	D, S		50.00	4
W. T. Jameson	4	30	28	1890	Bored, 8 inches	50	10		Horse	D, S		50.00	75
Eugene Verdier	4	30	28		Dug, 5 by 5 feet	10	7	61	do	S.		20.00	10
A. J. Gilman	1	30	27	1904	Bored, 8 inches	70	10	62	Gas, hand	D, S, I		60.00	200
I. A. Hiatt	1	30	27	1900?	Bored, 6 inches	18	6	60	Hand	D			
C. C. Stockton	2	30	27		do	64	6		Steam	D, S			
L. M. Keith	2	30	27		do	33	13		Hand	D			
Coffee & Glenn	2	30	27	1904	Bored, 8 inches	36	11	62	do	D			
Christ Mattly	2	30	27	1902	Bored, 6 inches	26	4	62	Gas	D	5		325
T. H. Dickey	11	30	27	1902	Bored, 2 inches	25	8	62	Hand	D			
Kern County Land Co	5	30	27	1904	do	25	10	62	do	D		7.00	
W. S. Tevis	4	30	27	1882?	Bored, 7 inches	450	7	68	Electric	D, I	49		

[a] Four wells.
[b] Cost of well and equipment combined.
[c] Three wells.
[d] Five wells.
[e] Two wells.

TABLE 62.—*Records of wells in Kern County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
Kern County Land Co.[a]	4	30	27	1899	Bored, 13 inches	70	10		Electric	I	175		
Do.[b]	4	30	27	1899	do	60	7		do	I	137		
Do.[a]	4	30	27	1899	do	113	7		do	I	250		
Do	8	30	27	1899	do	61	9		do	I	237		
Do	5	30	27	1899	do	129	9		do	I	134		
Do.[c]	6	30	27	1898	do	76	9		do	I	187		
Do.[d]	6	30	27	1899	do	151	9		} do	I	150		
	6	30	27		do	140	9						
Do.[a]	6	30	27	1900	do	96	13		do		176		
Do	3	30	26	1901	do	89	3		do	I	155		
Do	3	30	26	1899	do	101	11		do	I	275		
Do	4	30	26	1899	do	91	6		do	I	200		
Do	4	30	26	1901	do	87	6		do	I	250		
Do	4	30	26	1901	do	71	7		do	I	250		
Do	4	30	26		Bored, 6 inches	43	13		Horse	S			
Do	3	30	26		do	43	15		do	S			
Do	4	30	26		do	44	14	63	do	S			
Do	5	30	26		do	45	14		do	S			
Do	7	30	26		do	50	14		do	S			
Do	5	30	26		do	42	13	64	do	S			
Do	6	30	26		do	45	15		do	S			
Do	1	30	25		do	62	16		do	S			
Do	11	30	25	1897	do	40	10		do	S			
Do	16	30	25		Bored, 8 inches	42	12		do	S			
Do	20	30	25		Bored, 6 inches	50	14	64	do	S			
Do	20	30	25		do	50	14	62	do	S			
Do	20	30	25		Bored, 8 inches	50	14	63	do	D, S			
Do	27	30	25		Bored, 6 inches	60	12		do	S			
Southern Pacific Co	16	30	26		Bored, 8 inches	63	10	70	Steam	B	8		
C. D. Campbell	24	30	26	1901	Bored, 6 inches	45	13	72	Hand	D		$2,250.00	
Mrs. M. E. O'Hare	30	30	27	1895	do	68	12	68	Horse	D, S			
Kern County Land Co	19	30	27		do	55	10	68	do	D, S			
A. Williamson	30	30	27	1891	do	62	8	66	Hand	D			
Kern County Land Co	29	30	27	1905	do	52	8	64	do	D		26.00	$4
W. W. Frazer	20	30	27		do	50	10	66	do	D			
M. Reddy	18	30	27		do	70	4	68	do	D			
Freear Bros	28	30	27	1899	do	40	8	64	Horse	D, S		40.00	
C. Mattly	22	30	27	1898	do	40	5	64	Hand	D, S			

D. McNee	27	30	27		do	42	6	64	do	D, S			
Miller & Lux	23	30	27		Bored, 7 inches	66	5	64	do	D			
H. H. Gillum	23	30	27	1899?	Bored, 6 inches	15	5	60	do	D, S		20.00	
J. A. Shafter	13	30	27		do	40	9	64	do	D			
W. Orchard	14	30	27		Bored, 8 inches	73	9	64	do	D			
C. Kerr	14	30	27	1896	Bored, 6 inches	96	8	62	Horse	D, S		15.00	3
A. G. Lial	15	30	27		do	35	5	64	Hand	D			
Manual Gonzales	11	30	27	1904	Bored, 2 inches	16	6	62	do	D		40.00	3
H. F. Banks	11	30	27	1903	Bored, 1½ inches	12	7?	62	do	D, S			
T. S. Fultz	12	30	27	1903		40	5	62	Gas	D, S	10		150
T. A. Moncure	12	30	27		Bored, 6 inches	54	8	58	Wind	D			
W. T. Davis	7	30	28	1904	Bored, 10 inches	42	6?	64	Hand	D		75.00	
P. C. Castro	13	30	27	1903	Bored, 6 inches	72	7	61	Horse	D		54.00	50
C. F. Haperkern	18	30	28	1903	Bored, 7 inches	72	12	66	Hand	D			
Mrs. John Drow	13	30	27		Bored, 6 inches	23	5	66	do	D, S			
M. F. Silver	18	30	28	1898	do	42		66	do	D		33.00	3
Union Avenue school district	18	30	28	1893	do	73	12?	64	do	D		55.00	4
Geo. A. Rankins	8	30	28	1905	do	101	8?	64	do	D		90.00	
Geo. J. Frey	18	30	28	1902	do	51	12?	64		D, S		25.00	3
J. E. Mills	17	30	28	1897	Bored, 8 inches	85	8		Horse	S			
J. E. McCaffery	16	30	28		Bored	40	5		Gas	D			200
Jim Bernard	21	30	28		Bored, 6 inches	18	6	60	Hand	D			3
Fairfax school district	11	30	28		do	+100	19	66	do	D			4
P. Mill	12	30	28		do		27	78	Horse	D			25
Mr. Mocettini	12	30	28		Bored, 7 inches	62	22		Not raised	N			
W. H. Muller	12	30	28	1898	Bored, 10 inches	70	28?	66	Horse	D		90.00	7
Do	12	30	28	1905	do	125	26?			N		125.00	
J. W. Ingram	13	30	28		Bored, 6 inches	65	41		Horse	S			
M. Yancy	13	30	28	1895	Bored, 7 inches	125	60?	63	Wind	D		125.00	300
Lee Berges	13	30	28	1903	Bored, 6 inches	62	39	67	Horse	D		50.00	10
J. P. Schonetti	24	30	28	1903	do	51	40?	67	do	D		50.00	15
A. W. Wells	25	30	28	1895	do	51	30	67	Hand	D		40.00	
James Fix	36	30	28	1899	do	68	25	84	Horse	D	5	50.00	25
W. B. Myers	31	30	29	1896	Bored, 7 inches	68	24?		Wind	D		50.00	100
V. Moppin	30	30	29	1901	Bored, 6 inches	50	34?		Not raised	N		40.00	
F. J. Kincaid	32	30	29	1895	Bored, 7 inches	66	44	67	Hand	D		50.00	9
D. Donavan	6	31	29		Bored, 8 inches	44	42	66	do	D		35.00	2
J. T. Bate	36	30	28	1905	Bored, 9½ inches	194	30?		Gas	I		435.00	2,000
John McCaffrey	21	30	28	1894	Bored, 8 inches	83	7?	62	Hand	D, S		20.00	3
John O'Neil	19	30	28	1895	do	60	8?		Wind	D, S		25.00	
W. M. Hall	30	30	28	1901		45	30?	65	Hand	D		22.00	5
S. Hamilton	30	30	28	1895	Bored, 6 inches	52	12	70	do	D			
Fairview school district	24	30	27		do	73	6.5	65	do	D			
Jacob A. Shaffer	24	30	27	1903?	do	46	4.5	62	Gas	D, S		30.00	600
C. Holtby	24	30	27		do	30	5	62	Hand	D			
Jean Pomroy	23	30	27		Bored, 7 inches	55	7	62	do	D			
C. L. Dennen	25	30	27	1899	Bored, 6 inches	36	6	61	do	D			
Do	25	30	27	1904	do	85	5	60	do	D			
Mrs. Allen	25	30	27	1904?	do	107	3?	66	do	D, S		80.00	

a Four wells. *b* Five wells. *c* Three wells. *d* Two wells.

TABLE 62.—*Records of wells in Kern County*—Continued.

Owner.	Location. Section.	Location. Township south.	Location. Range east.	Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
Alexander Berges	30	30	28		Bored, 6 inches	90	6	67	Hand	D			
W. M. Beekman	29	30	28	1900	Bored, 8 inches	90	8?		Gas	D, S			$400
C. D. Morris	31	30	28	1904	Bored, 6 inches	60	6	61	Hand	D		$45.00	4
Charley Chung	32	30	28	1901	Dug, 3 by 3 feet	11	9	62	do	D			
R. R. P. Fox	30	30	28		Bored, 6 inches	160	5	70	Gas	D	2		
J. G. McKee	36	30	27		do	93	7	68	Hand	D			
G. Burton	36	30	27		do	43	8	66	do	D			
R. E. Houghton	31	30	28		do	65	10?	66	do	D		35.00	10
P. M. Wilkerson	36	30	27	1902	Bored, 2 inches	52	8	64	do	D		27.00	3
S. Curnel	25	30	27	1902	Bored, 6 inches	45	8	64	do	D		30.00	5
M. L. Replogle	36	30	27		Bored, 8 inches	90	6	70	do	D, S			
H. A. Emerson	36	30	27	1902	Bored, 6 inches	50	10	64	Horse	D, S		25.00	75
S. Stiltson	35	30	27	1904	Bored, 7 inches	80	9	66	Gas	D, S	11		
A. A. Doyle	35	30	27	1904	Bored, 6 inches	56	10	66	Hand	D			
J. W. Parish	3	31	27	1892		40	12	66	do	D, S			
Christ Ruedy	34	30	27	1901	Bored, 8 inches	64	8	68	Steam	D, S	5	50.00	35
E. E. Pyle	34	30	27	1892	do	71	10	62	Gas	I	55	40.00	60
Do	3	31	27	1899	Bored, 6 inches	29	8	67	Hand	S		12.00	3
Mrs. A. H. May	4	31	27	1890	do	60	6	67	do	D		30.00	3
E. M. Ashe	34	30	27	1892	do	67	12	72	Horse	D, S		60.00	
H. R. Frecar	29	30	27	1892	do	45	7	64	Wind	D, S			
J. B. McCutchen	29	30	27	1890	do	42	8	62	Hand	D			
J. Adams	32	30	27	1892	Bored	60		64	Horse	D, S			
V. Stoner	32	30	27	1887	Bored, 8 inches	800	0	72	Artesian	D, S	Small.	2,400.00	
M. F. Pearson	29	30	27	1898	Bored, 6 inches	62	9	67	Hand	D		30.00	4
V. Stoner	30	30	27	1894	Bored, 12 inches	200		66	Steam	I	200		
Do	30	30	27	1898	Bored, 8 inches	86	6	65	do	D, S	8	40.00	
H. W. Jackson	31	30	27	1896	Bored	67	8	68	Hand	D			
Kern County Land Co.	36	30	26		Bored, 10 inches		0	70	Artesian	S			
Do	26	30	26		do	950	0	72	do	S	*a* 2		
Do	34	30	26		Bored, 8 inches	+500	0	69	do	S	3		
Do	31	30	26		do		0	70	do	S			
Do	11	31	25		Bored, 6 inches	305	0	80	do	S			
Do	17	31	26		Bored, 8 inches	312	0	84	do	S			
G. Barker	1	31	26		Bored, 6 inches		0	75	do	D, S			
H. Piper	1	31	26		do	40	5	66	Horse			20.00	75
J. S. Ellis	6	31	27	1897	Bored	50	7	68	Steam	D	26	25.00	30
C. Mattly	12	31	26		Bored, 4 inches	560	0	70	Artesian	S	4		

Do	12	31	26		Bored, 8 inches	500	0	74	do	S	22		
Kern County Land Co	7	31	27		Bored, 6 inches		0	77	do	S			
P. Corti	18	31	27	1900	Bored, 10 inches	30	10	64	Horse	D		39.00	50
T. Corsett	8	31	27		Bored, 6 inches	48	9	66	Hand	D			
J. Zumwaldt	6	31	27			59	11	68	do	D			
R. S. Ash	6	31	27	1902	Bored, 6 inches	45	9	66	do	D			
R. L. Emery	31	30	27	1897	Bored	57	9	68	do	D			
J. Zumwaldt	32	30	27		Bored, 6 inches	25	10	68	do	D			
C. Baptista	5	31	27	1900	do	48	9	68	do	D		25.00	4
C. Williams	5	31	27			54	12	68	do	D		27.00	6
J. Herod	4	31	27		Bored, 6 inches	50	10	68	do	D			
L. F. Johndrone	4	31	27		do	50	8	66	do	D			
J. W. Webster	3	31	27	1890	do	64	9	68	do	D		48.00	4
Mr. Jealy	10	31	27		do	62	9	67	do	D			
J. Vernachio	1	31	27	1903	do	50	10	64	do	D, S			
O. R. Taylor	1	31	27	1901	do	48	5	68	do	D		24.00	3
D. E. Josephi	7	31	28	1893?	Bored, 8 inches	150		65	Wind	D, S		150.00	80
Walter Abby	5	31	28		Bored, 6 inches	33	2	64	Hand	D		25.00	4
S. A. Williams	5	31	28	1904	do	25	3.5	62	do	S		16.00	3
T. W. Glover	5	31	28	1901	do	27	2	66	do	D		20.00	4
A. S. Taylor	9	31	28	1902	Bored	45	3?	66	do	D		20.00	3
R. E. Houghton	8	31	28	1903	Bored, 8 inches	156	0	66	Artesian	I	5		
L. E. Formway	5	51	28	1902	Bored, 2 inches	28	10?	64	Hand	D		6.00	10
N. H. Stoner	9	31	28	1901	Bored, 6 inches	112	0	66	Artesian	D	a 1	112.00	
R. E. Hoton	7	31	28		do	400	0	67	do	S	4		
C. D. Oldershaw	7	31	28		do		3		Horse	D			25
Tim Flannigan	17	31	28	1901	do	100	1	67	do	D		75.00	20
F. A. Langdon	12	31	28	1904	Bored, 12 inches	240	15?		Gas	I		240.00	
A. J. Fowler	13	31	28	1904	Bored, 13 inches	53	16		Not raised	N			
H. A. Blodgeth	12	31	28	1893	Bored, 7 inches	70	28		Hand	D		50.00	30
V. H. Plummer	12	31	28		Bored, 6 inches	43	27	66	do	D		25.00	4
C. B. Alexander	7	31	29	1892	Bored, 8 inches	80	32?		Horse	D		60.00	
W. D. Knight	7	31	29	1901	Bored, 7 inches	82	30?	68	do	D		50.00	40
Mr. Deegan	18	31	29		Bored, 10 inches	49	41		do	D			
F. T. Rosendahl	18	31	29		do	44	27		do	D			
J. C. Castle?	18	31	29	1899	Bored, 6 inches	55	20?	68	do	D		36.00	45
F. H. Langdon	20	31	29	1894	Bored, 8 inches	62	14?		do	D		60.00	
J. Cuda	20	31	29	1897	Bored, 7 inches	55	20	66	Hand	D		55.00	18
J. F. Bennett	20	31	29		Bored, 6 inches	38	26	63	do	D		23.00	6
A. M. Towne	19	31	29		Bored, 5 inches	1,040	9		Not raised	N			
	22	31	29		Bored, 7 inches	70	58		Horse	N			
Richard Derdy	15	31	29		Bored, 8 inches	73	68		Not raised	N		55.00	
A. J. Allen	23	31	29		do	+100	98		Horse	N			
	24	31	29		Bored, 7 inches	86	76		do	N		65.00	25
G. H. Deacon	26	31	29		Bored, 8 inches	57	56		Not raised	N		45.00	
M. E. Baker	26	31	29		Bored, 7 inches	45	44.5		Hand	D			
Fred Hill	34	31	29	1897	do	48	30		Horse	D		35.00	20
J. Brockman	28	31	29	1890	do	58	24		Not raised	N		45.00	
Beheran Domingo	28	31	28	1852	Bored, 8 inches		2		Horse	D			
Kern County Land Co	21	31	28	1875	do	350	0		Artesian	S			
Do	20	31	28	1887	Bored, 7 inches	900	0	70	do	D	1		

a Yield estimated or statement of owner taken.

TABLE 62.—*Records of wells in Kern County*—Continued.

Owner.	Location.			Year completed.	Type and diameter of well.	Depth of well.	Depth to water level.	Temperature of water.	Method of lift.	Use of water.	Yield.	Cost of well.	Cost of machinery.
	Section.	Township south.	Range east.										
						Feet.	*Feet.*	°*F.*			*Miner's inches.*		
Jacob Shank	18	31	28		Bored, 6 inches	80	4	66	Wind	D		$60.00	$150
R. T. Baker	19	31	28	1899	do	87	8?	63	Hand	D		45.00	8
Kern County Land Co.	29	31	28		Bored, 7 inches		0	66	Artesian	S			
Do	32	31	28		do		0	66	do	S	3		
Do	32	31	28		do		0	68	do	S			
Do	31	31	28		do		0	68	do	S			
Mrs. M. Johnson	19	31	28	1903	Bored, 6 inches	80	3	68	Hand	D		40.00	3
W. R. Shafter	24	31	27		Bored, 8 inches	620	0		Artesian	D, S			
Kern County Land Co.	20	31	27		Bored, 10 inches	650	0	76	do	S			
Do	19	31	27	1899	Bored, 12 inches	1,395	0	72	do	S	2		
Do	25	31	26		Bored, 6 inches		0	74	do	S			
Miller & Lux	28	31	26		Bored, 10 inches		0	78	do	S			
Kern County Land Co.	32	31	26	1899	Bored, 4 inches	415	0	78	do	D, S	18		
Do	6	32	26	1900	do	416	0	79	do	S	18		
Do	4	32	26	1900	do	286	0	74	do	S	25		
Do	2	32	26	1900	Bored, 6 inches	345	0	78	do	S	16		
Miller & Lux	6	32	27		do		0	77	do	S			
Do	6	32	27		do	77	7	63	Horse	D, S			
Kern County Land Co.	30	31	27	1898	Bored, 8 inches	645	0	74	Artesian	S	23		
Do	30	31	27	1898	Bored, 4 inches	645	0	78	do	S	18		
Do	30	31	27		Bored, 10 inches		0	73	do	D, S	3		
Do	32	31	27		Bored, 4 inches		0	74	do	S	3		
Do	33	31	27		Bored, 10 inches		0	74	do	S	8		
Miller & Lux	5	32	27		do		0	74	do	S	20		
Kern County Land Co.	4	32	27	1899	Bored, 2 inches	582	0	74	do	S	4		
Do	3	32	27		Bored, 6 inches	29	4	65	Horse	B, S		20.00	30
Do	5	32	28		Bored, 7 inches		0	67	Artesian				
Do	11	32	27		Hydraulic, 4 inches		0	70	do	S			
Do	15	32	27		do	271	0	66	do	S			
Do	9	32	27	1902	Bored, 4 inches	507	0	74	do	S	2		
Do	8	32	27	1897	Bored, 3 inches	378	0	74	do	S	3		
Do	16	32	27	1904	Bored, 6 inches	648	0	74	do	D, S	7		
Do	21	32	27	1900	Bored, 3 inches	896	0	75	do	S	3		
Do	22	32	27		Hydraulic, 2 inches		0	65	do	S			
Do	13	32	27		Hydraulic, 4 inches		0	69	do	S			
Do	25	32	27		do		0	68	do	S			
Do	25	32	27		do		0	68	do	S			
Do	25	32	27		Bored, 8 inches		0	70	do	N			

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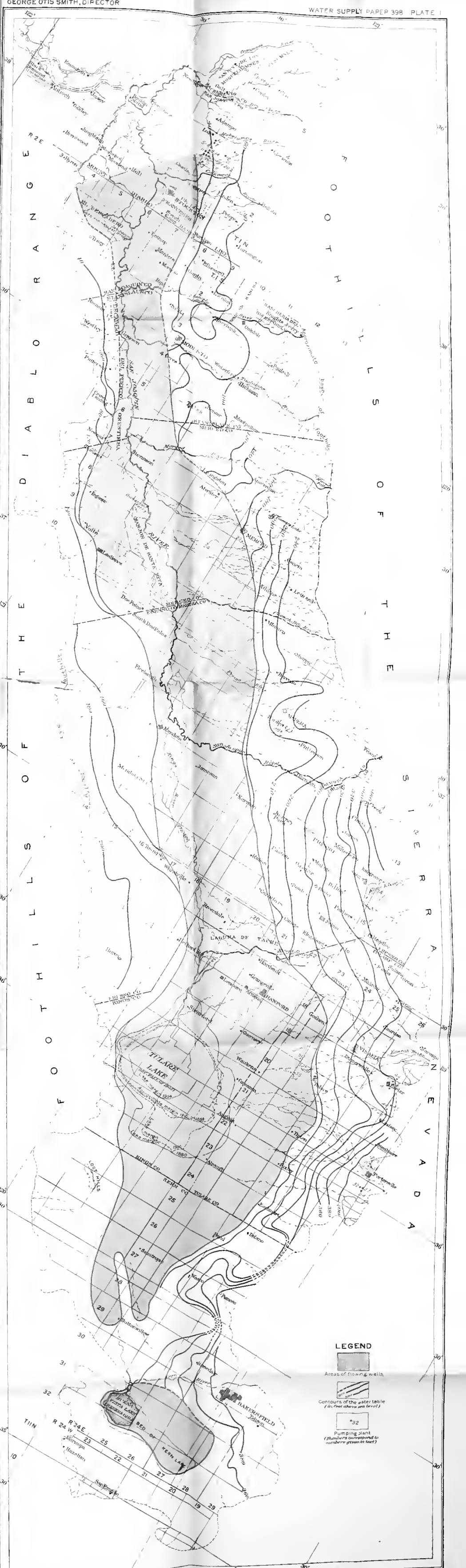


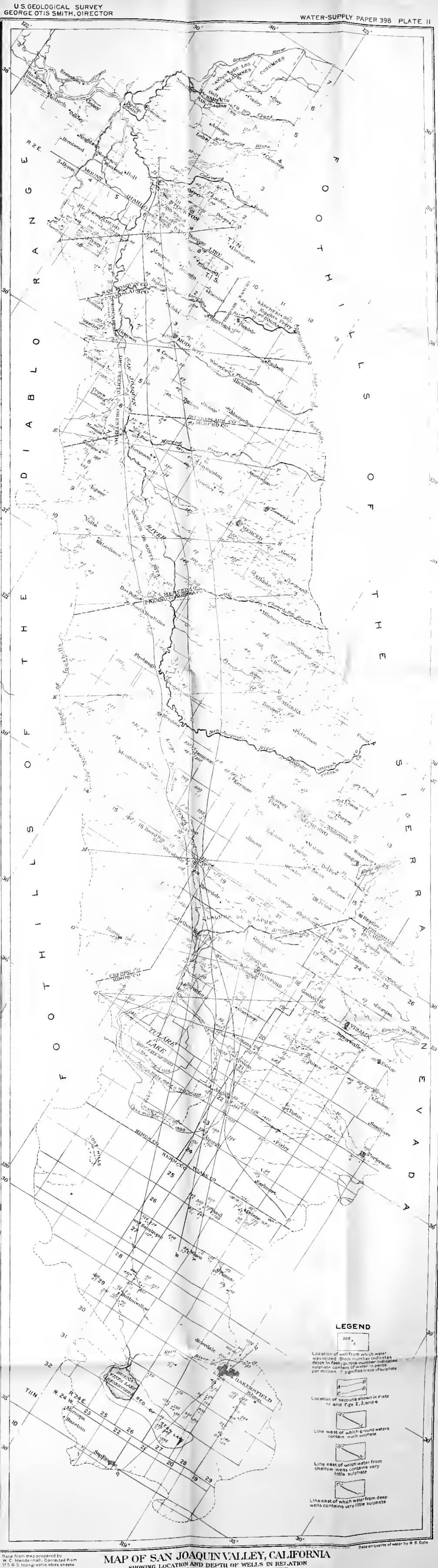
Base from map prepared by W. C. Mendenhall. Corrected from U.S.G.S. topographic atlas sheets

MAP OF SAN JOAQUIN VALLEY, CALIFORNIA
SHOWING ARTESIAN AREAS, GROUND-WATER LEVELS AND LOCATION OF PUMPING PLANTS

Scale $\frac{1}{500,000}$

1915

Artesian areas and ground-water levels by W. C. Mendenhall. Pumping plants by Herman Stabler



Base from map prepared by W. C. Mendenhall. Corrected from U. S. G. S. topographic atlas sheets

MAP OF SAN JOAQUIN VALLEY, CALIFORNIA

SHOWING LOCATION AND DEPTH OF WELLS IN RELATION TO SULPHATE CONTENT OF GROUND WATER

Scale $\frac{1}{500,000}$

5 0 5 10 15 20 Miles

10 0 10 20 Kilometers

1915